US006731632B1

(12) **United States Patent**
**Takahashi et al.**

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(45) **Date of Patent: May 4, 2004**

(54) **INTERNETWORKING SYSTEM AND METHOD**

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(73) Assignee: **Fujitsu Limited**, Kawasaki (JP)

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(30) **Foreign Application Priority Data**

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Dec. 15, 1999 (JP) ..... 11-355513

(51) **Int. Cl.**[7] ..... **H04L 12/28**; H04J 3/16

(52) **U.S. Cl.** ..... **370/392**; 370/401; 370/466

(58) **Field of Search** ..... 370/254, 400, 370/401, 389, 386, 392, 466, 469, 352–356; 709/249, 227, 230, 311

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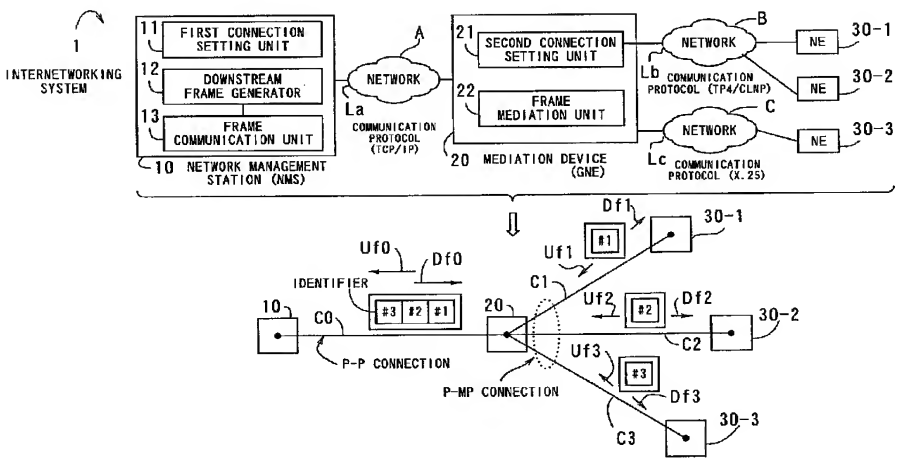
* cited by examiner

*Primary Examiner*—Duc Ho
(74) *Attorney, Agent, or Firm*—Katten Muchin Zavis Rosenman

(57) **ABSTRACT**

An internetworking system and method enabling efficient communication between networks that use different protocols. A network management station comprises a first connection setting unit, a downstream frame generator, and a frame communication unit. The first connection setting unit establishes a first connection over a network A to reach a gateway network element. The downstream frame generator produces a downstream frame containing identifiers of remote network elements. The frame communication unit sends out the downstream frame through the established first connection, and/or processes an upstream frame received through the same. The gateway network element serves as a mediation device, comprising a second connection setting unit and a frame mediation unit. The second connection setting unit establishes a second connection reaching the network elements, over networks B and C whose protocols are different from that of the network A. The frame mediation unit mediates the transport of downstream frames toward the network elements through the second connection. It also mediates the transmission of upstream frames toward the network management station.

**13 Claims, 51 Drawing Sheets**



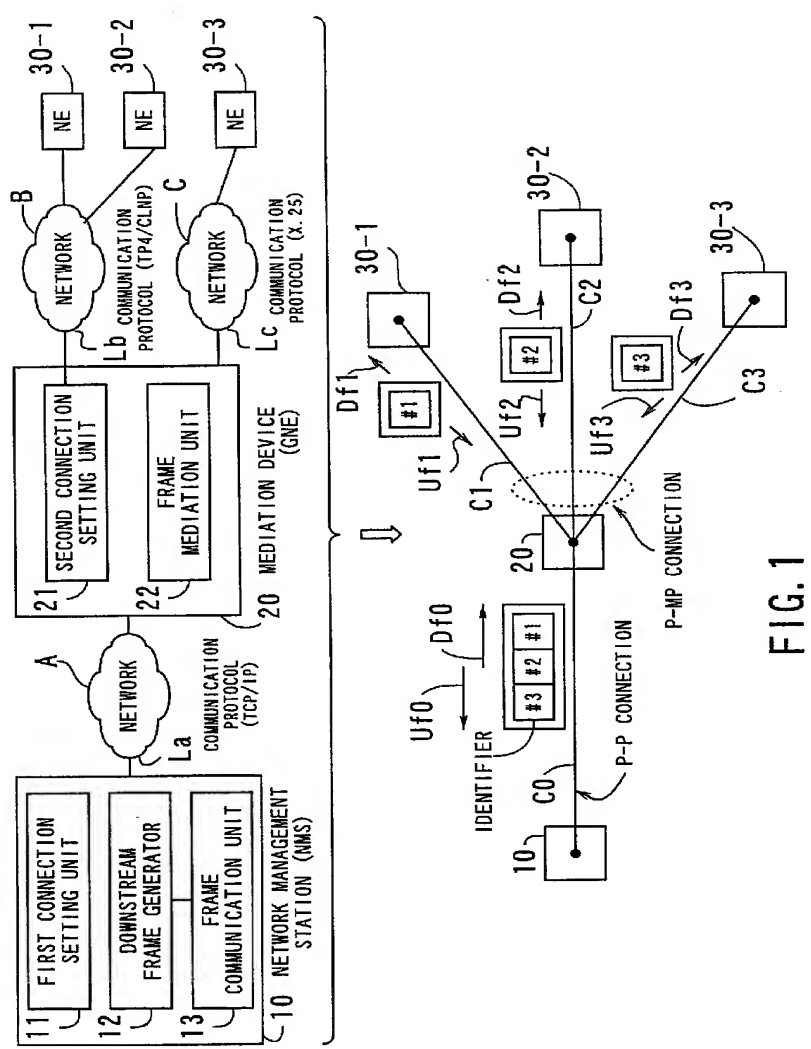

1
INTERNETWORKING SYSTEM
10 NETWORK MANAGEMENT STATION (NMS)
11 FIRST CONNECTION SETTING UNIT
12 DOWNSTREAM FRAME GENERATOR
13 FRAME COMMUNICATION UNIT
La COMMUNICATION PROTOCOL (TCP/IP)
A NETWORK
20 MEDIATION DEVICE (GNE)
21 SECOND CONNECTION SETTING UNIT
22 FRAME MEDIATION UNIT
Lb COMMUNICATION PROTOCOL (TP4/CLNP)
B NETWORK
Lc COMMUNICATION PROTOCOL (X.25)
C NETWORK
30-1 NE
30-2 NE
30-3 NE
Df0
Df1
Df2
Df3
Uf0
Uf1
Uf2
Uf3
IDENTIFIER
#1
#2
#3
C0
C1
C2
C3
P-P CONNECTION
P-MP CONNECTION

FIG. 1

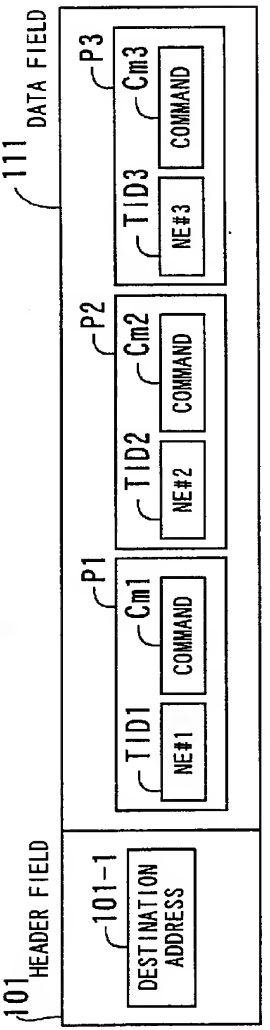

DfO DOWNSTREAM FRAME
101 HEADER FIELD
101-1 DESTINATION ADDRESS
111 DATA FIELD
P1
TID1
NE#1
Cm1
COMMAND
P2
TID2
NE#2
Cm2
COMMAND
P3
TID3
NE#3
Cm3
COMMAND

FIG. 2 (A)

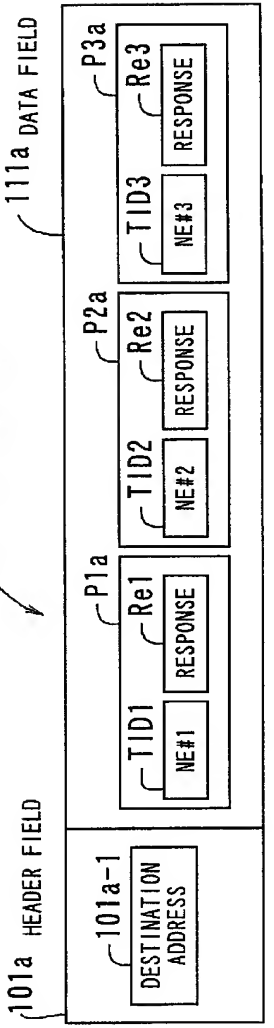

UfO UPSTREAM FRAME
101a HEADER FIELD
101a-1 DESTINATION ADDRESS
111a DATA FIELD
P1a
TID1
NE#1
Re1
RESPONSE
P2a
TID2
NE#2
Re2
RESPONSE
P3a
TID3
NE#3
Re3
RESPONSE

FIG. 2 (B)

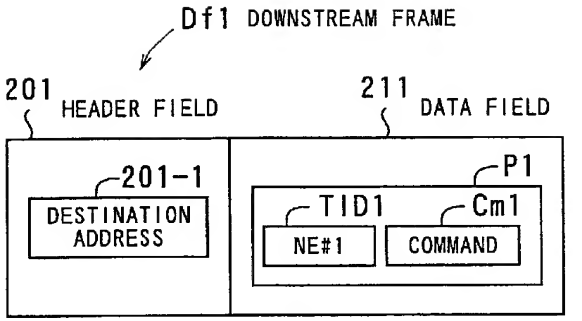

Df1 DOWNSTREAM FRAME
201
HEADER FIELD
211
DATA FIELD
201-1
DESTINATION ADDRESS
P1
TID1
Cm1
NE#1
COMMAND

FIG. 3(A)

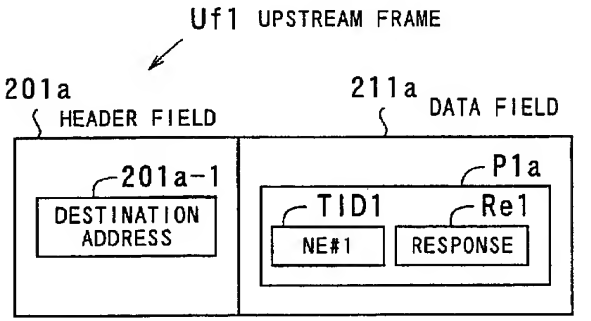

Uf1 UPSTREAM FRAME
201a
HEADER FIELD
211a
DATA FIELD
201a-1
DESTINATION ADDRESS
P1a
TID1
Re1
NE#1
RESPONSE

FIG. 3(B)

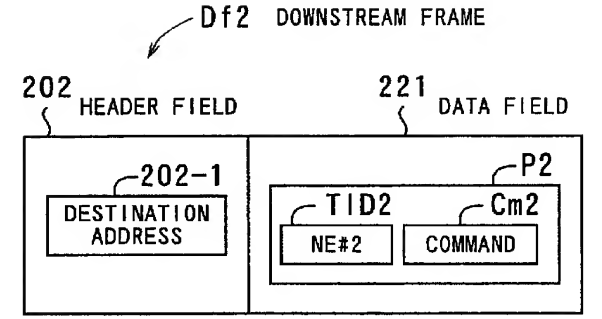

Df2 DOWNSTREAM FRAME
202 HEADER FIELD
221 DATA FIELD
202-1
DESTINATION ADDRESS
P2
TID2
Cm2
NE#2
COMMAND

FIG. 4(A)

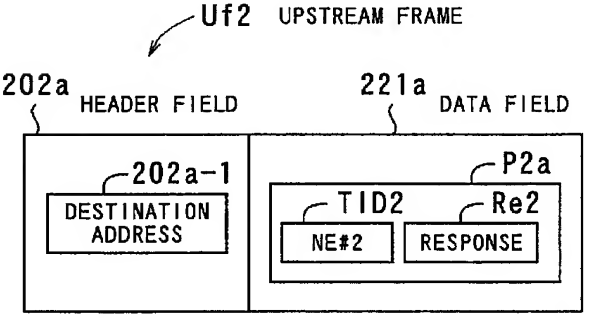

Uf2 UPSTREAM FRAME
202a HEADER FIELD
221a DATA FIELD
202a-1
DESTINATION ADDRESS
P2a
TID2
Re2
NE#2
RESPONSE

FIG. 4(B)

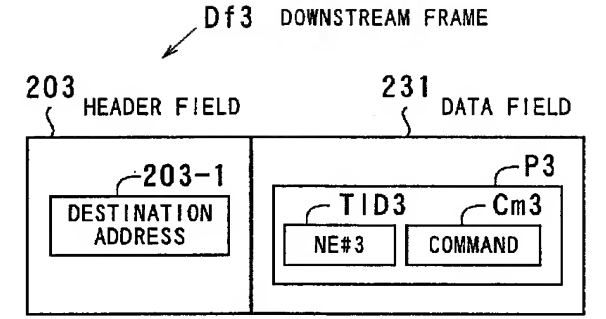

Df3 DOWNSTREAM FRAME
203 HEADER FIELD
231 DATA FIELD
203-1
DESTINATION ADDRESS
P3
TID3
Cm3
NE#3
COMMAND

FIG. 5(A)

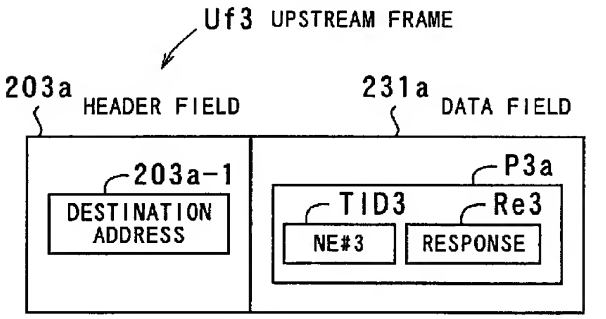

Uf3 UPSTREAM FRAME
203a HEADER FIELD
231a DATA FIELD
203a-1
DESTINATION ADDRESS
P3a
TID3
Re3
NE#3
RESPONSE

FIG. 5(B)

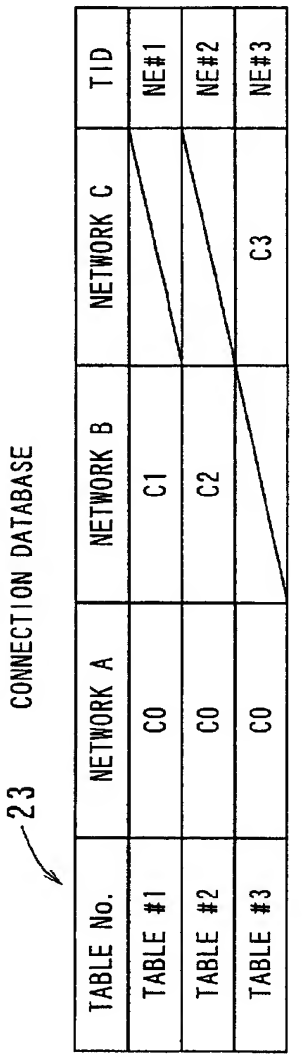

23
CONNECTION DATABASE
TABLE No.
NETWORK A
NETWORK B
NETWORK C
TID
TABLE #1
C0
C1
NE#1
TABLE #2
C0
C2
NE#2
TABLE #3
C0
C3
NE#3

FIG. 6

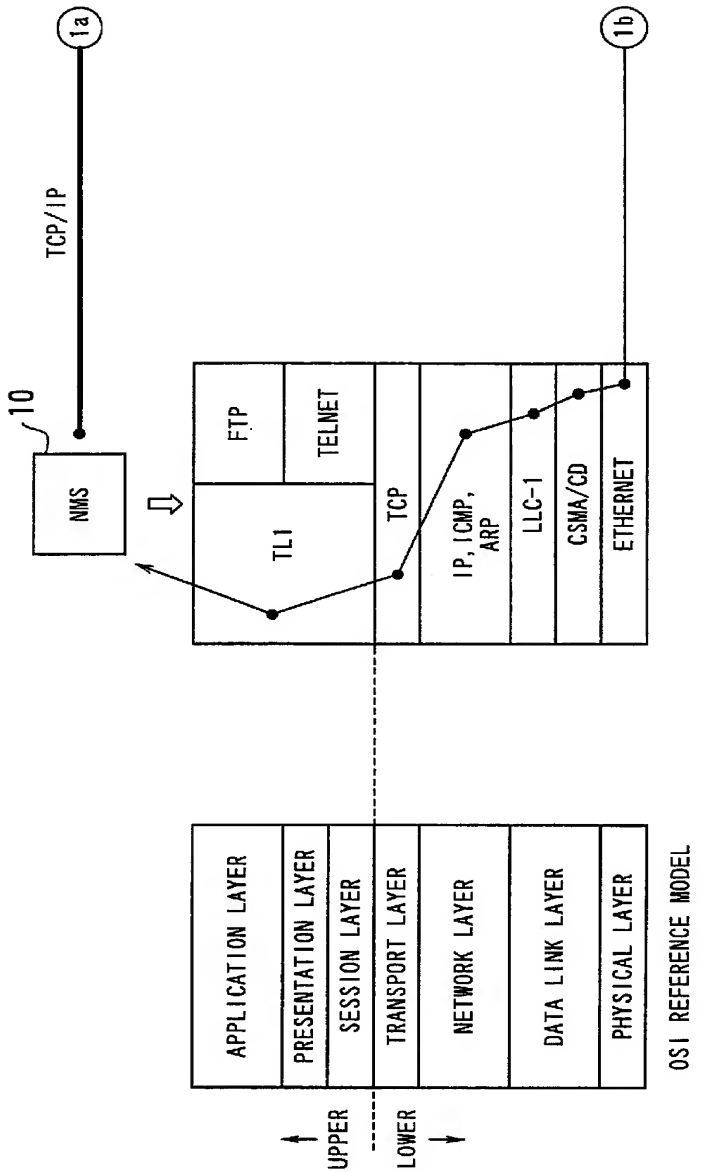

1a
TCP/IP
10
NMS
TL1
FTP
TELNET
TCP
IP, ICMP, ARP
LLC-1
CSMA/CD
ETHERNET
1b
APPLICATION LAYER
PRESENTATION LAYER
SESSION LAYER
TRANSPORT LAYER
NETWORK LAYER
DATA LINK LAYER
PHYSICAL LAYER
UPPER
LOWER
OSI REFERENCE MODEL

FIG. 7

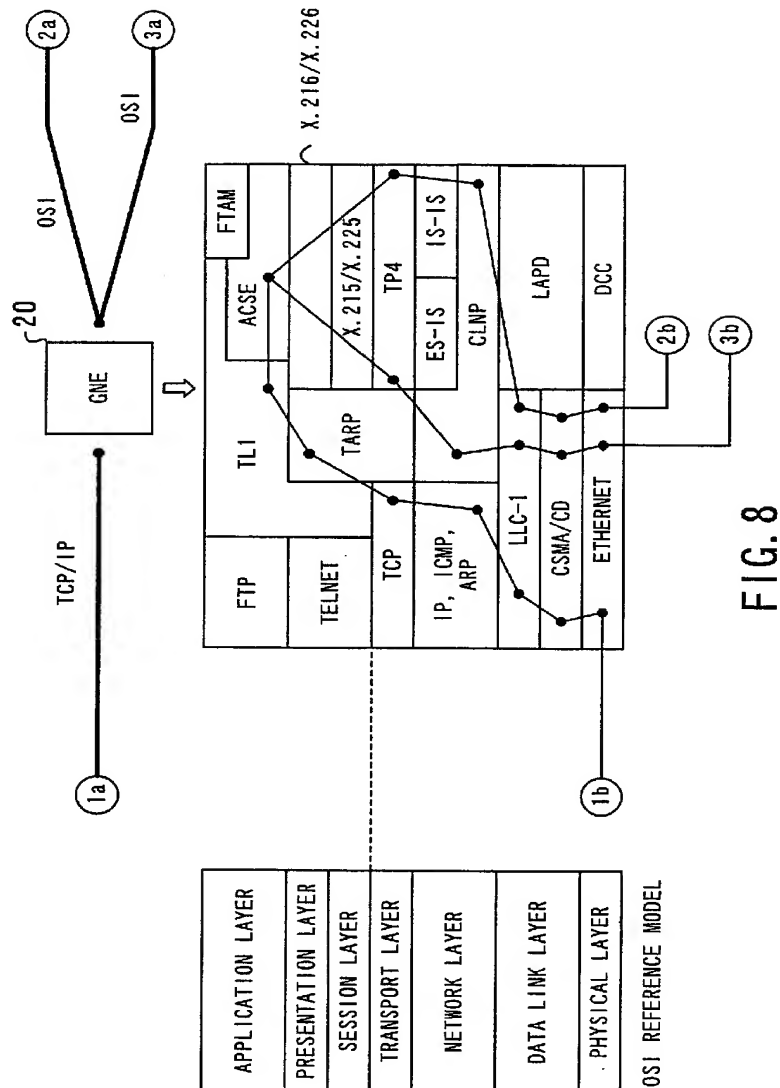

2a
3a
OSI
OSI
20
GNE
TCP/IP
1a
X.216/X.226
FTAM
ACSE
TL1
TARP
X.215/X.225
TP4
ES-IS
IS-IS
CLNP
LAPD
DCC
FTP
TELNET
TCP
IP, ICMP, ARP
LLC-1
CSMA/CD
ETHERNET
2b
3b
1b
APPLICATION LAYER
PRESENTATION LAYER
SESSION LAYER
TRANSPORT LAYER
NETWORK LAYER
DATA LINK LAYER
PHYSICAL LAYER
UPPER
LOWER
OSI REFERENCE MODEL

FIG. 8

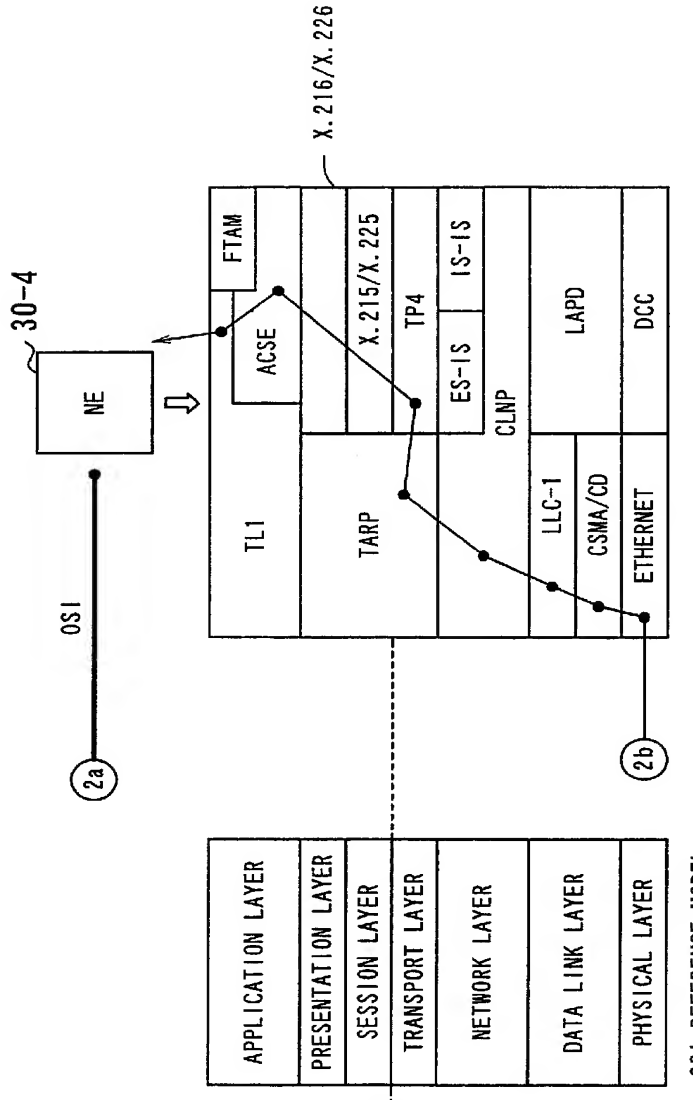

X.216/X.226
30-4
NE
OSI
2a
FTAM
ACSE
TL1
TARP
X.215/X.225
TP4
ES-IS
IS-IS
CLNP
LLC-1
CSMA/CD
ETHERNET
LAPD
DCC
2b
APPLICATION LAYER
PRESENTATION LAYER
SESSION LAYER
TRANSPORT LAYER
NETWORK LAYER
DATA LINK LAYER
PHYSICAL LAYER
UPPER
LOWER
OSI REFERENCE MODEL

FIG. 9

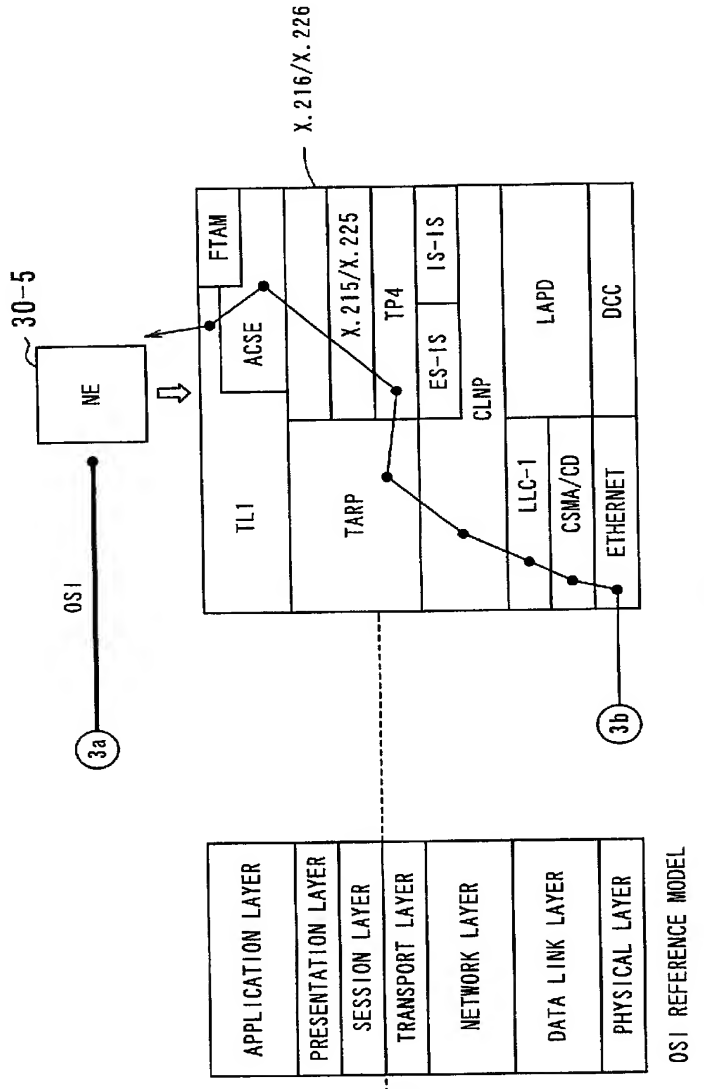

30-5
NE
OSI
3a
X.216/X.226
FTAM
ACSE
X.215/X.225
TP4
ES-IS
IS-IS
CLNP
LAPD
DCC
TL1
TARP
LLC-1
CSMA/CD
ETHERNET
3b
APPLICATION LAYER
PRESENTATION LAYER
SESSION LAYER
TRANSPORT LAYER
NETWORK LAYER
DATA LINK LAYER
PHYSICAL LAYER
UPPER
LOWER
OSI REFERENCE MODEL

FIG. 10

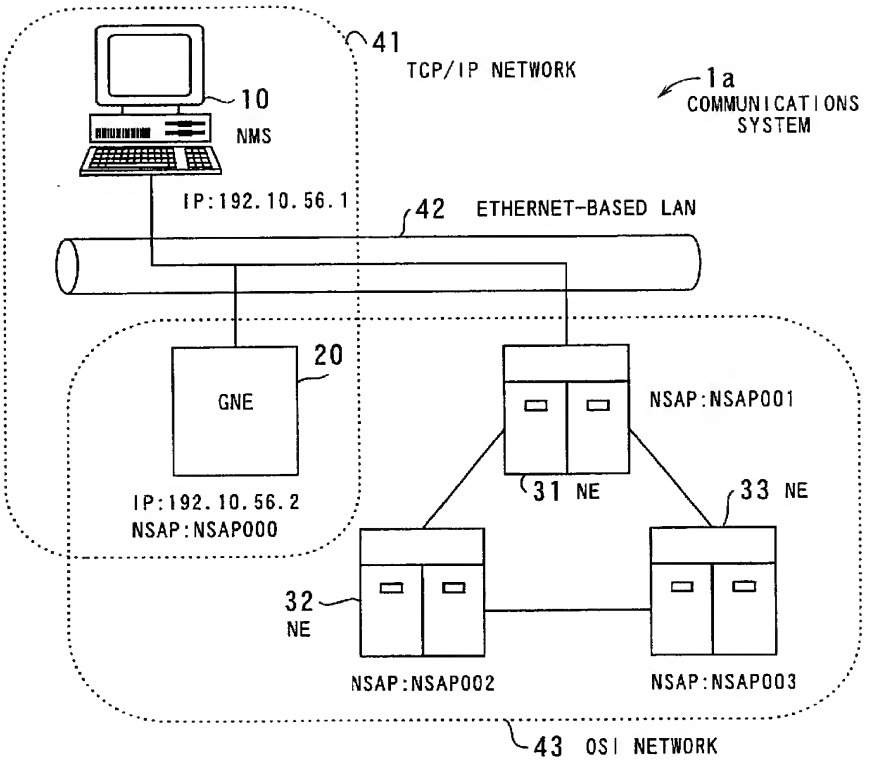

41
TCP/IP NETWORK
1a
COMMUNICATIONS SYSTEM
10
NMS
IP:192.10.56.1
42
ETHERNET-BASED LAN
20
GNE
IP:192.10.56.2
NSAP:NSAP000
NSAP:NSAP001
31 NE
33 NE
32
NE
NSAP:NSAP002
NSAP:NSAP003
43 OSI NETWORK

FIG. 11

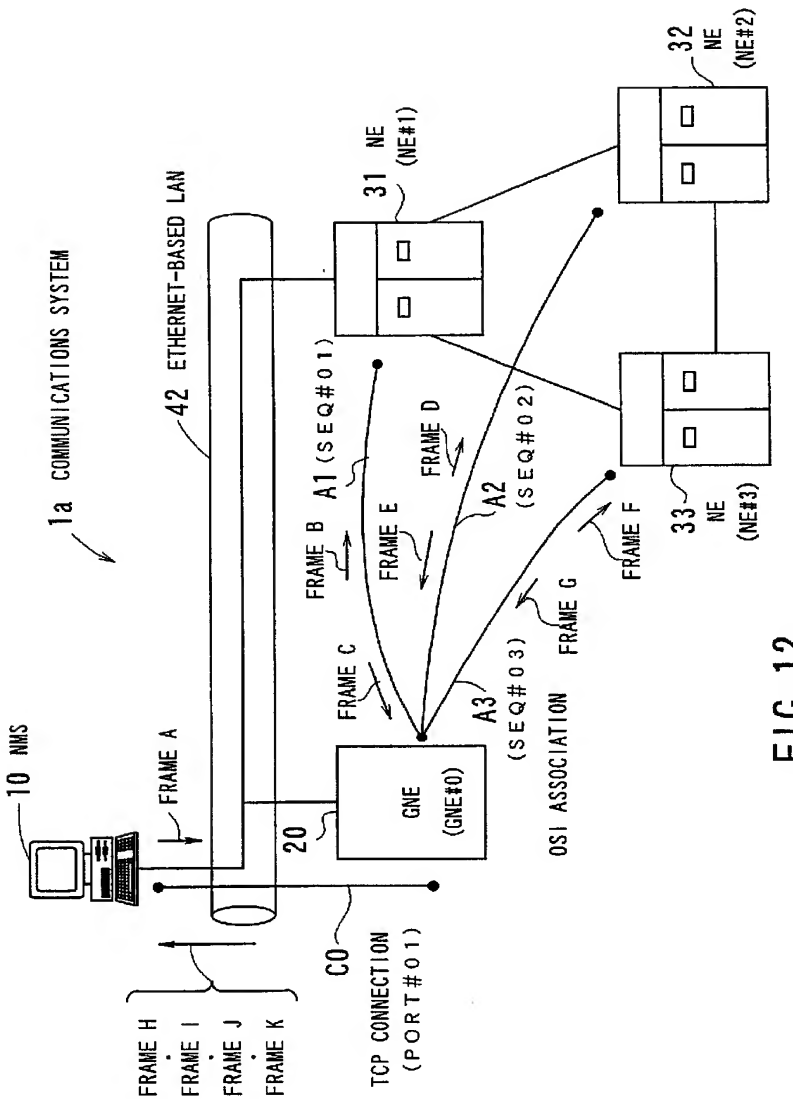

1a COMMUNICATIONS SYSTEM
10 NMS
FRAME A
42 ETHERNET-BASED LAN
20
GNE
(GNE#0)
C0
TCP CONNECTION
(PORT#01)
FRAME H
FRAME I
FRAME J
FRAME K
FRAME B
A1 (SEQ#01)
FRAME C
FRAME D
FRAME E
A2 (SEQ#02)
A3 (SEQ#03)
OSI ASSOCIATION
FRAME F
FRAME G
31 NE (NE#1)
32 NE (NE#2)
33 NE (NE#3)

FIG. 12

23 CONNECTION DATABASE

| TABLE No. | TCP/IP NETWORK | OSI NETWORK | TID |
|---|---|---|---|
| TABLE #1 | PORT#01 | SEQ#01 | NE#1 |
| TABLE #2 | PORT#01 | SEQ#02 | NE#2 |
| TABLE #3 | PORT#01 | SEQ#03 | NE#3 |

FIG. 13

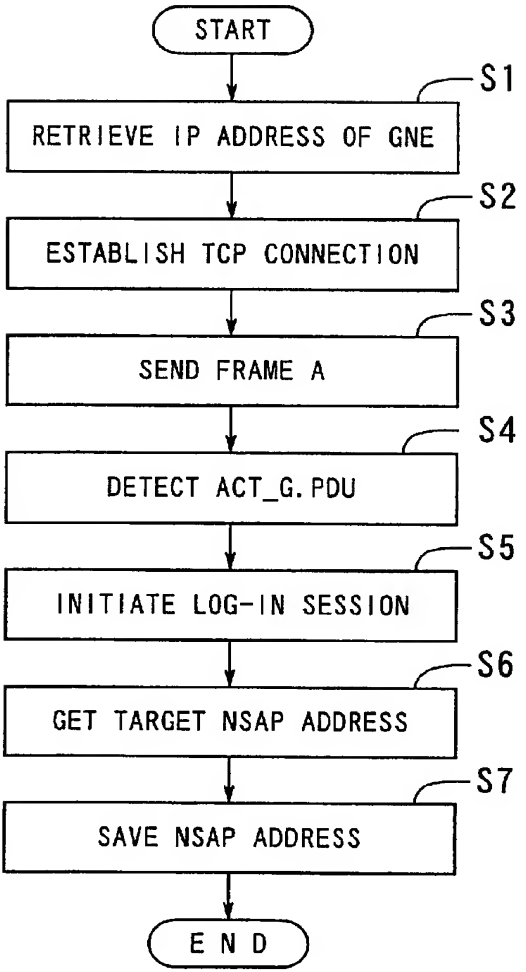

START
S1
RETRIEVE IP ADDRESS OF GNE
S2
ESTABLISH TCP CONNECTION
S3
SEND FRAME A
S4
DETECT ACT_G.PDU
S5
INITIATE LOG-IN SESSION
S6
GET TARGET NSAP ADDRESS
S7
SAVE NSAP ADDRESS
E N D

FIG. 14

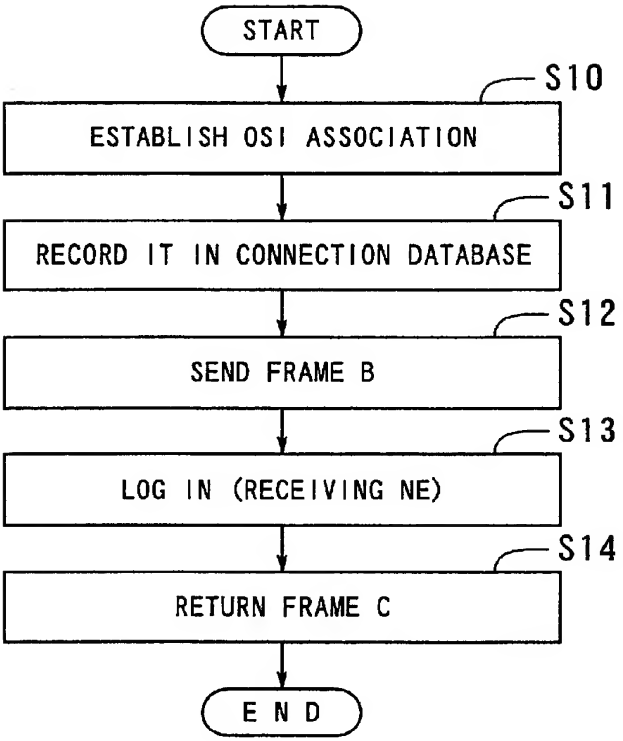

START
S10
ESTABLISH OSI ASSOCIATION
S11
RECORD IT IN CONNECTION DATABASE
S12
SEND FRAME B
S13
LOG IN (RECEIVING NE)
S14
RETURN FRAME C
END

FIG. 15

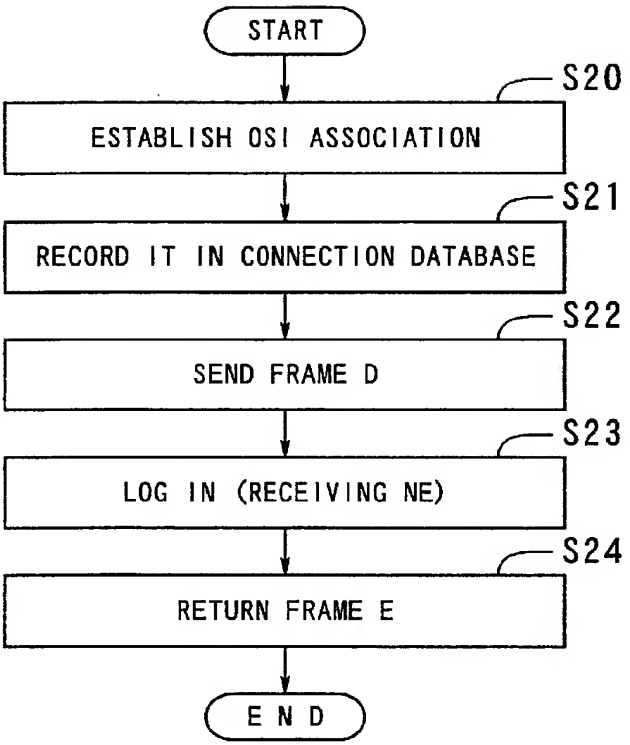

START
S20
ESTABLISH OSI ASSOCIATION
S21
RECORD IT IN CONNECTION DATABASE
S22
SEND FRAME D
S23
LOG IN (RECEIVING NE)
S24
RETURN FRAME E
END

FIG. 16

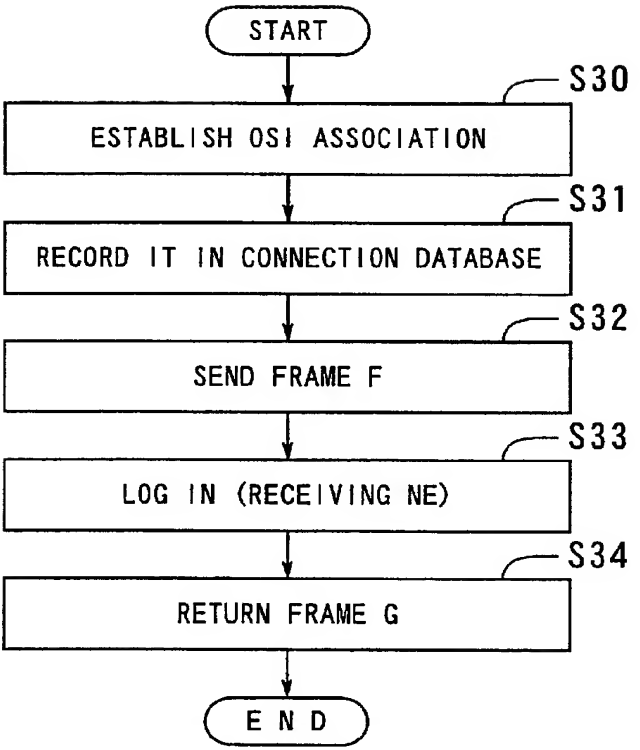

START
S30
ESTABLISH OSI ASSOCIATION
S31
RECORD IT IN CONNECTION DATABASE
S32
SEND FRAME F
S33
LOG IN (RECEIVING NE)
S34
RETURN FRAME G
END

FIG. 17

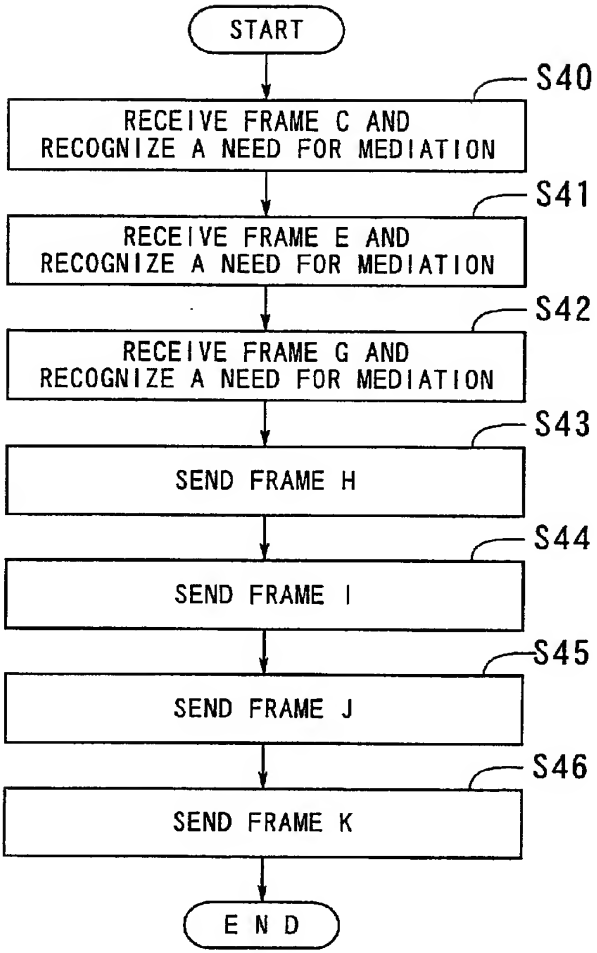

START
S40
RECEIVE FRAME C AND RECOGNIZE A NEED FOR MEDIATION
S41
RECEIVE FRAME E AND RECOGNIZE A NEED FOR MEDIATION
S42
RECEIVE FRAME G AND RECOGNIZE A NEED FOR MEDIATION
S43
SEND FRAME H
S44
SEND FRAME I
S45
SEND FRAME J
S46
SEND FRAME K
END

FIG. 18

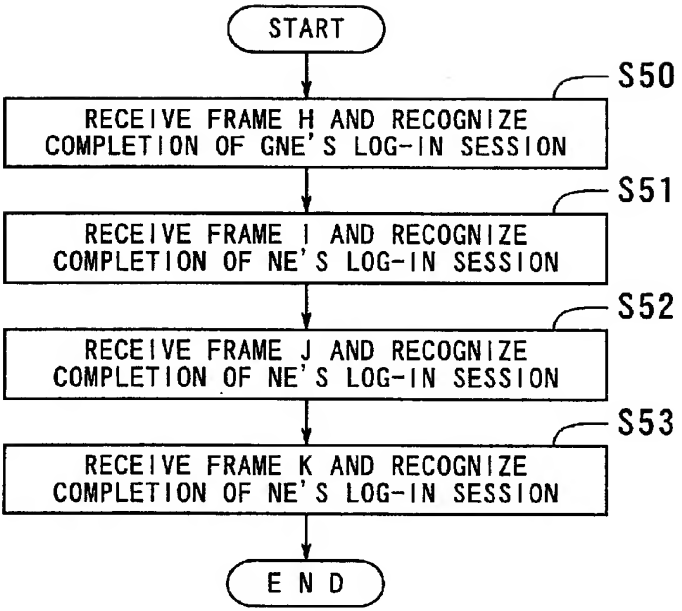

START
S50
RECEIVE FRAME H AND RECOGNIZE COMPLETION OF GNE'S LOG-IN SESSION
S51
RECEIVE FRAME I AND RECOGNIZE COMPLETION OF NE'S LOG-IN SESSION
S52
RECEIVE FRAME J AND RECOGNIZE COMPLETION OF NE'S LOG-IN SESSION
S53
RECEIVE FRAME K AND RECOGNIZE COMPLETION OF NE'S LOG-IN SESSION
END

FIG. 19

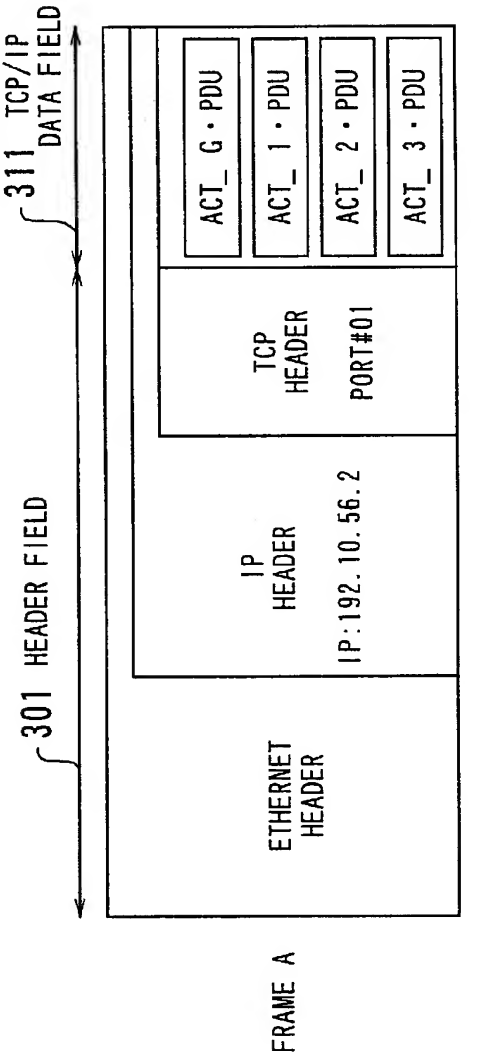

FRAME A
301 HEADER FIELD
311 TCP/IP DATA FIELD
ETHERNET HEADER
IP HEADER
IP:192.10.56.2
TCP HEADER
PORT#01
ACT_ G・PDU
ACT_ 1・PDU
ACT_ 2・PDU
ACT_ 3・PDU

FIG. 20

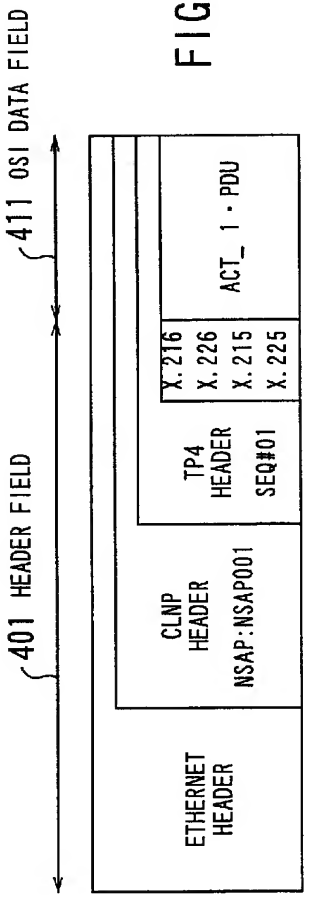



FIG. 21(A)

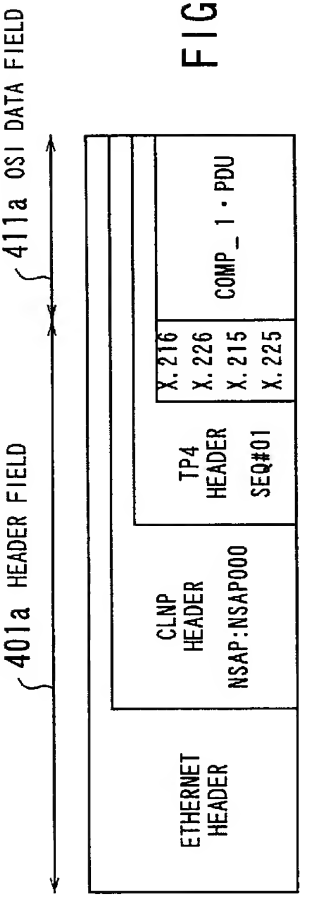



FIG. 21(B)

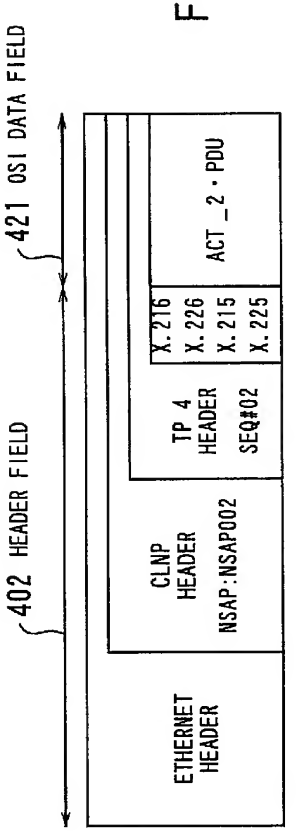



FIG. 22 (A)

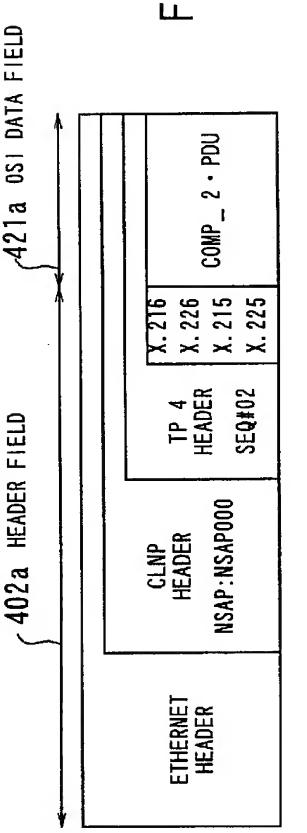



FIG. 22 (B)

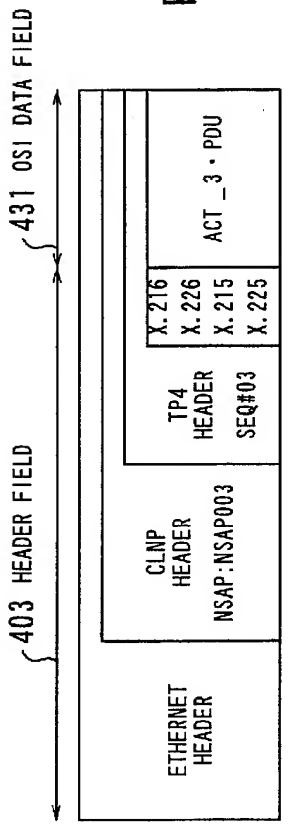



FIG. 23(A)

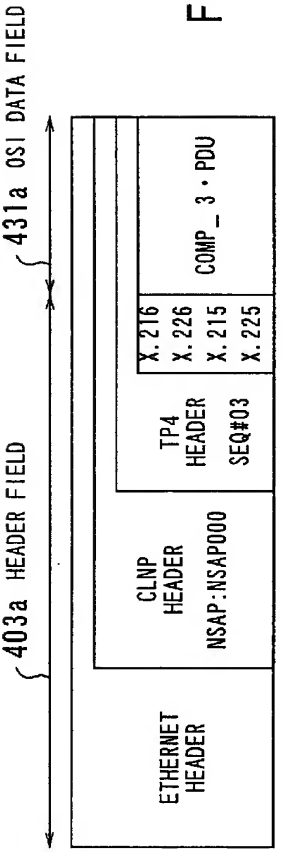



FIG. 23(B)

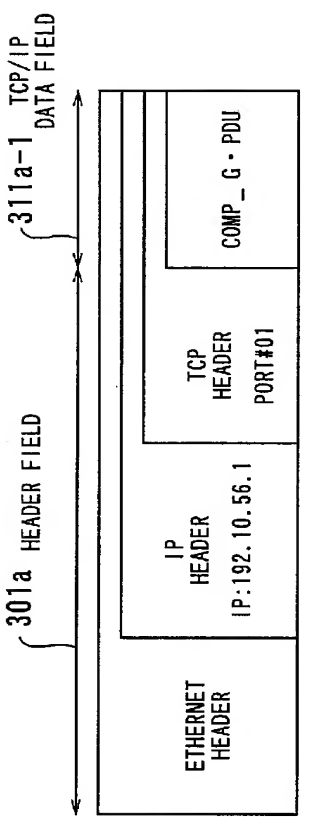



FIG. 24(A)

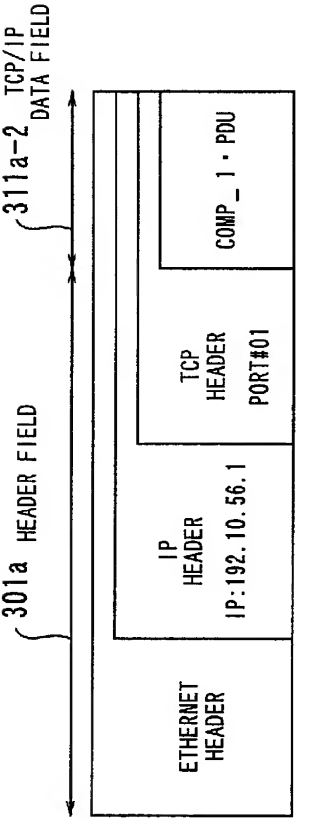



FIG. 24(B)

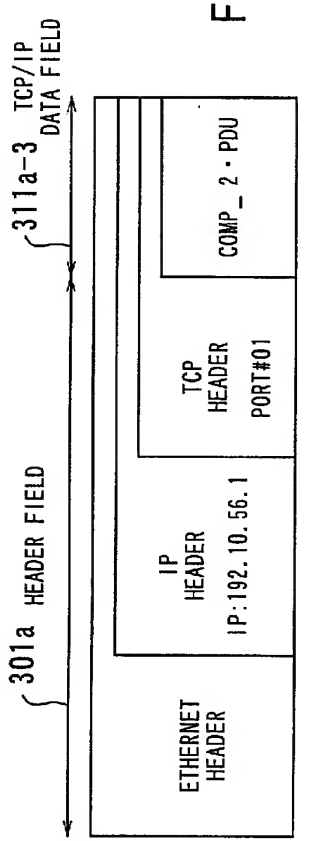



FIG. 25(A)

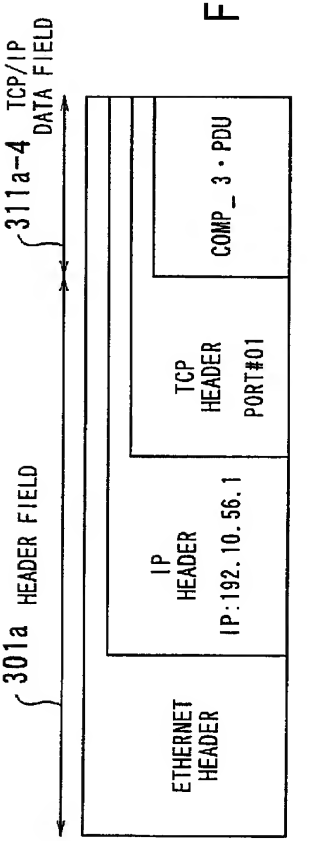



FIG. 25(B)

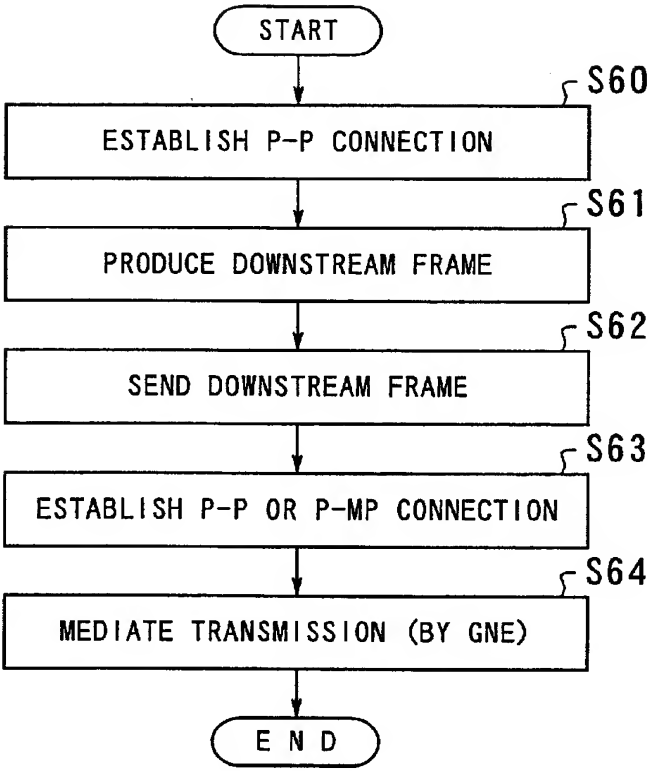

START
S60
ESTABLISH P-P CONNECTION
S61
PRODUCE DOWNSTREAM FRAME
S62
SEND DOWNSTREAM FRAME
S63
ESTABLISH P-P OR P-MP CONNECTION
S64
MEDIATE TRANSMISSION (BY GNE)
E N D

FIG. 26

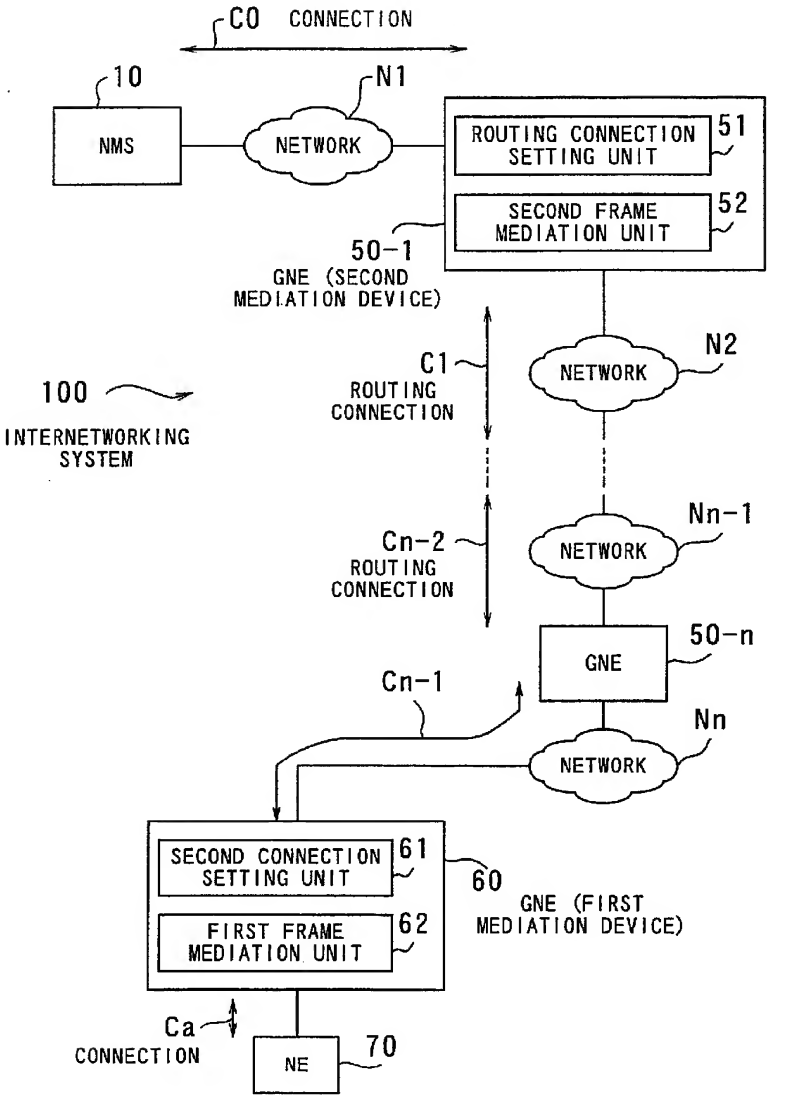

C0 CONNECTION
10
NMS
N1
NETWORK
ROUTING CONNECTION SETTING UNIT
51
SECOND FRAME MEDIATION UNIT
52
50-1
GNE (SECOND MEDIATION DEVICE)
100
INTERNETWORKING SYSTEM
C1
ROUTING CONNECTION
N2
NETWORK
Cn-2
ROUTING CONNECTION
Nn-1
NETWORK
GNE
50-n
Cn-1
Nn
NETWORK
SECOND CONNECTION SETTING UNIT
61
60
GNE (FIRST MEDIATION DEVICE)
FIRST FRAME MEDIATION UNIT
62
Ca
CONNECTION
NE
70

FIG. 27

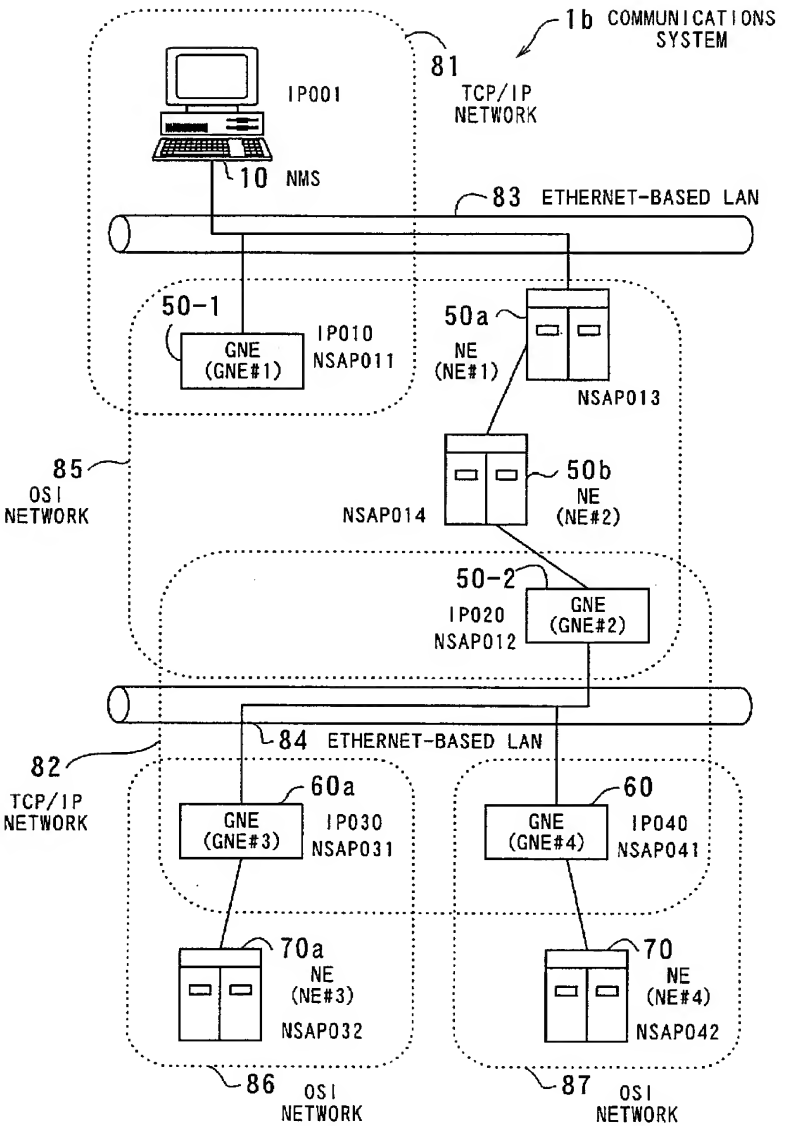

1b COMMUNICATIONS SYSTEM
81
TCP/IP NETWORK
IP001
10 NMS
83 ETHERNET-BASED LAN
50-1
GNE (GNE#1)
IP010
NSAP011
50a
NE (NE#1)
NSAP013
85
OSI NETWORK
NSAP014
50b
NE (NE#2)
50-2
IP020
NSAP012
GNE (GNE#2)
84 ETHERNET-BASED LAN
82
TCP/IP NETWORK
60a
GNE (GNE#3)
IP030
NSAP031
60
GNE (GNE#4)
IP040
NSAP041
70a
NE (NE#3)
NSAP032
70
NE (NE#4)
NSAP042
86 OSI NETWORK
87 OSI NETWORK

FIG. 28

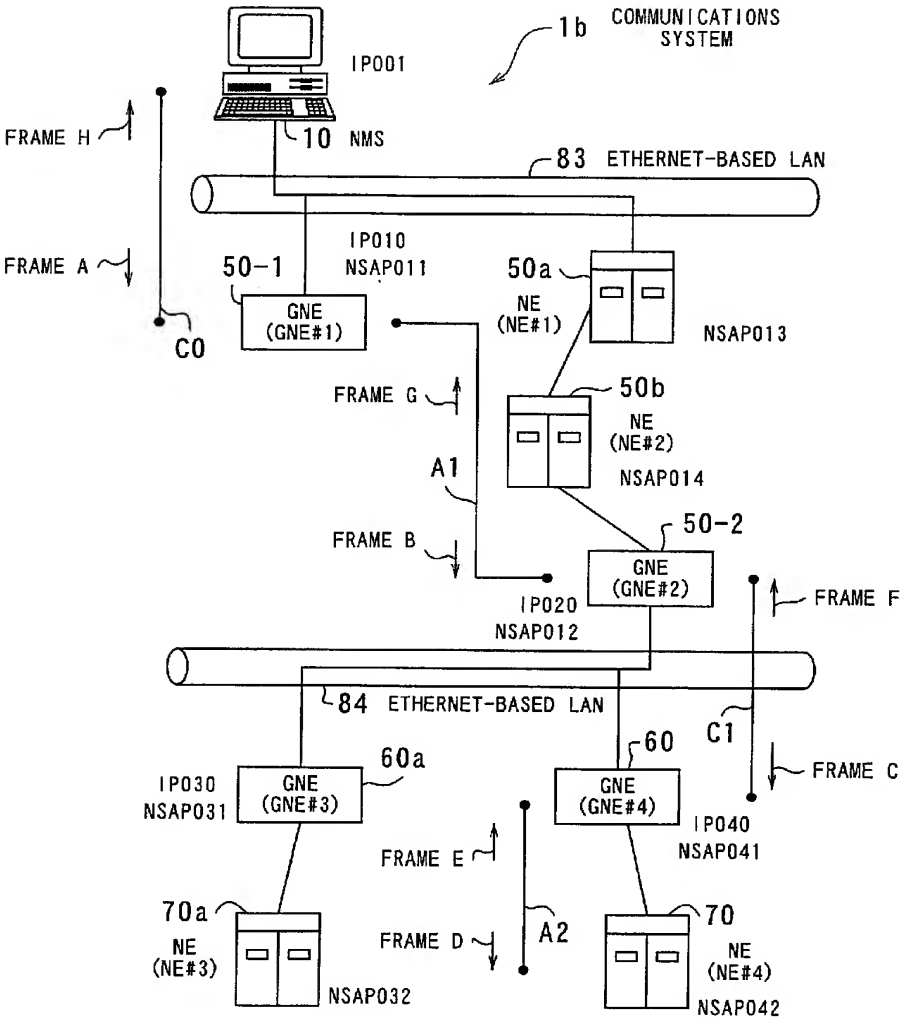

1b
COMMUNICATIONS SYSTEM
IP001
10 NMS
83 ETHERNET-BASED LAN
FRAME H
FRAME A
IP010
NSAP011
50-1
GNE (GNE#1)
C0
50a
NE (NE#1)
NSAP013
FRAME G
50b
NE (NE#2)
NSAP014
A1
FRAME B
50-2
GNE (GNE#2)
IP020
NSAP012
FRAME F
84 ETHERNET-BASED LAN
C1
60
60a
IP030
NSAP031
GNE (GNE#3)
GNE (GNE#4)
FRAME C
IP040
NSAP041
FRAME E
FRAME D
A2
70a
NE (NE#3)
NSAP032
70
NE (NE#4)
NSAP042

FIG. 29

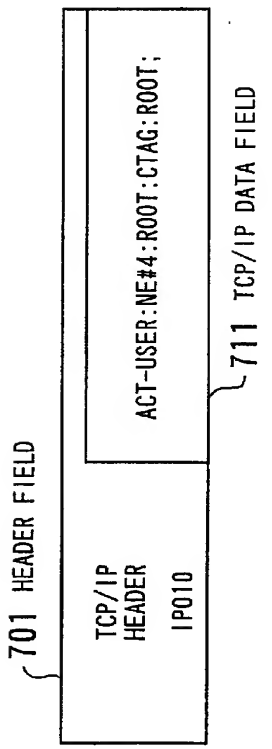



FIG. 30(A)

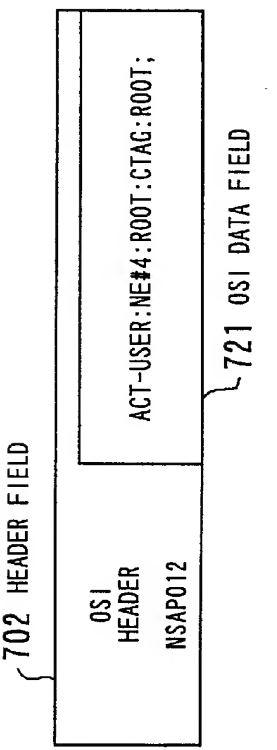



FIG. 30(B)

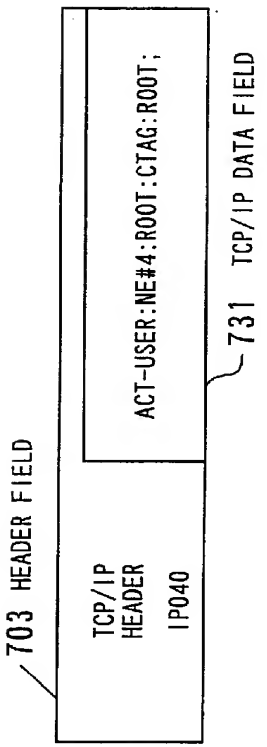



FIG. 31 (A)

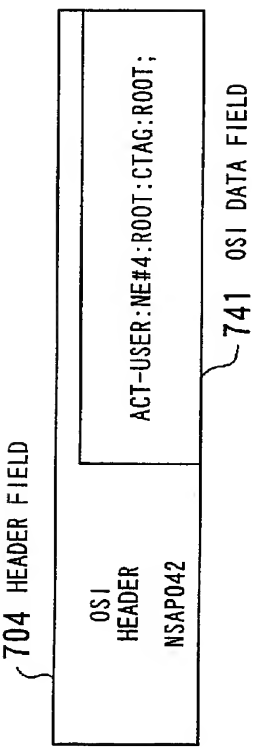



FIG. 31 (B)

FIG. 32(A)

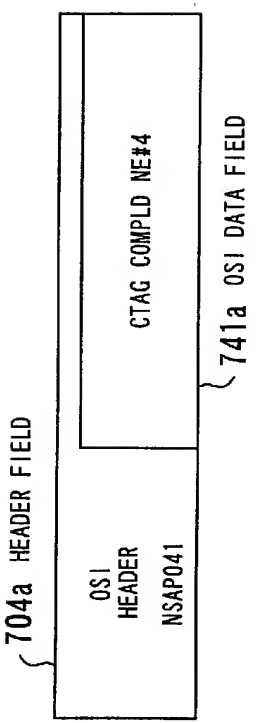



FIG. 32(B)

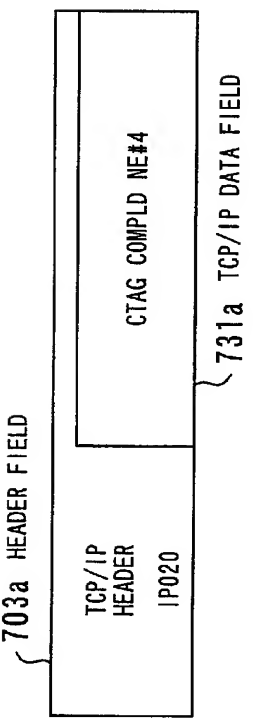


FIG. 33(A)

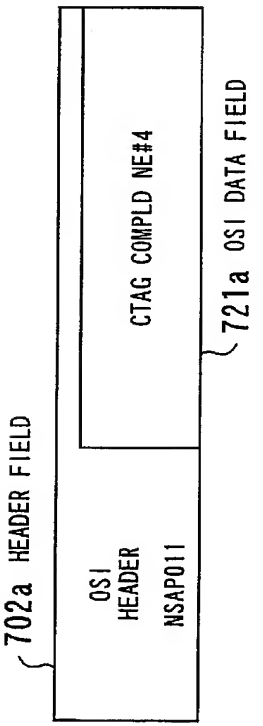
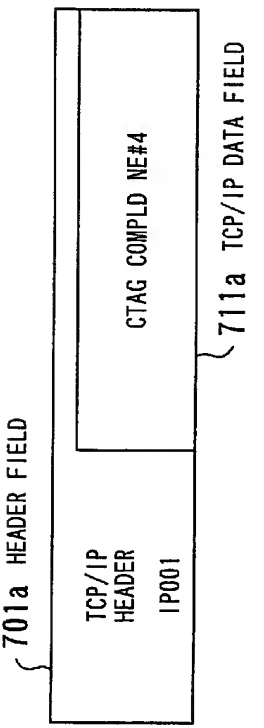



FIG. 33(B)



T1

| IP ADDRESS | TID |
|---|---|
| IP030 | GNE#3 |
| IP030 | NE#3 |
| IP040 | GNE#4 |
| IP040 | NE#4 |

FIG. 34

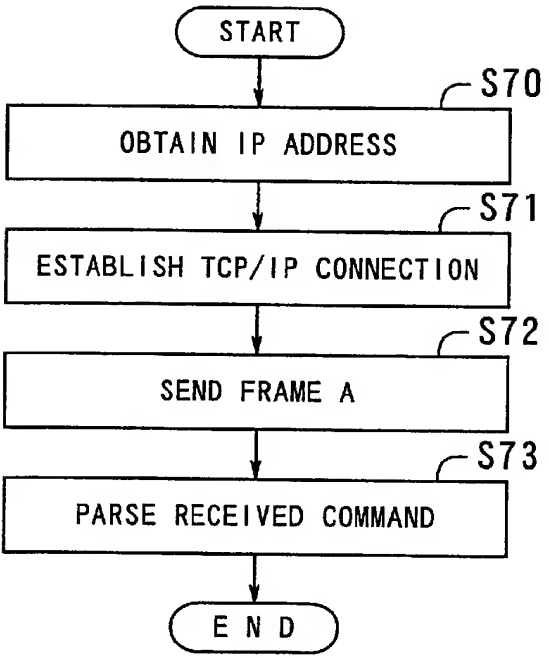

START
S70
OBTAIN IP ADDRESS
S71
ESTABLISH TCP/IP CONNECTION
S72
SEND FRAME A
S73
PARSE RECEIVED COMMAND
E N D

FIG. 35

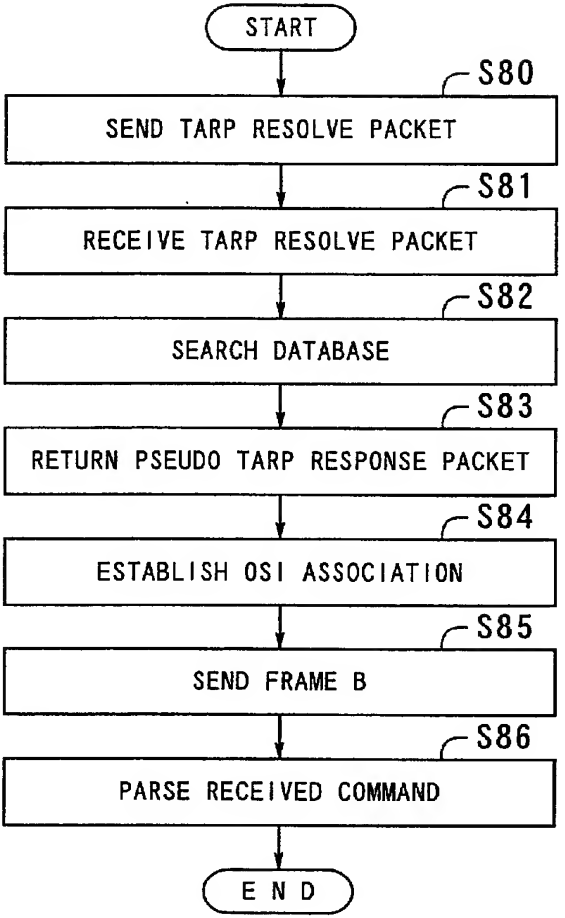

START
S80
SEND TARP RESOLVE PACKET
S81
RECEIVE TARP RESOLVE PACKET
S82
SEARCH DATABASE
S83
RETURN PSEUDO TARP RESPONSE PACKET
S84
ESTABLISH OSI ASSOCIATION
S85
SEND FRAME B
S86
PARSE RECEIVED COMMAND
END

FIG. 36

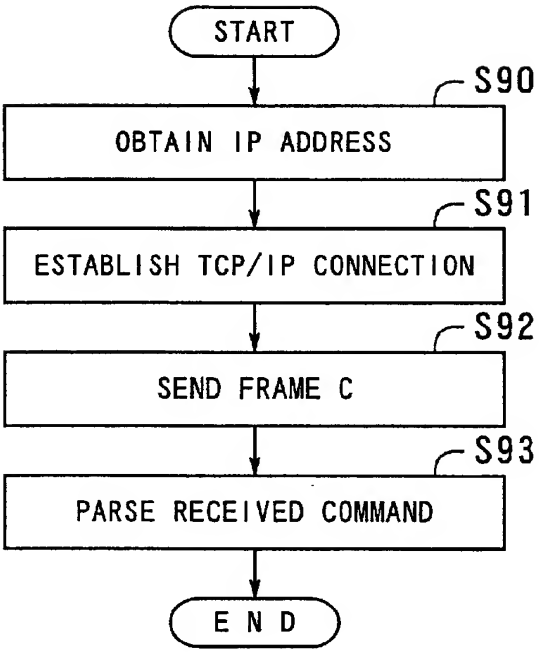

START
S90
OBTAIN IP ADDRESS
S91
ESTABLISH TCP/IP CONNECTION
S92
SEND FRAME C
S93
PARSE RECEIVED COMMAND
E N D

FIG. 37

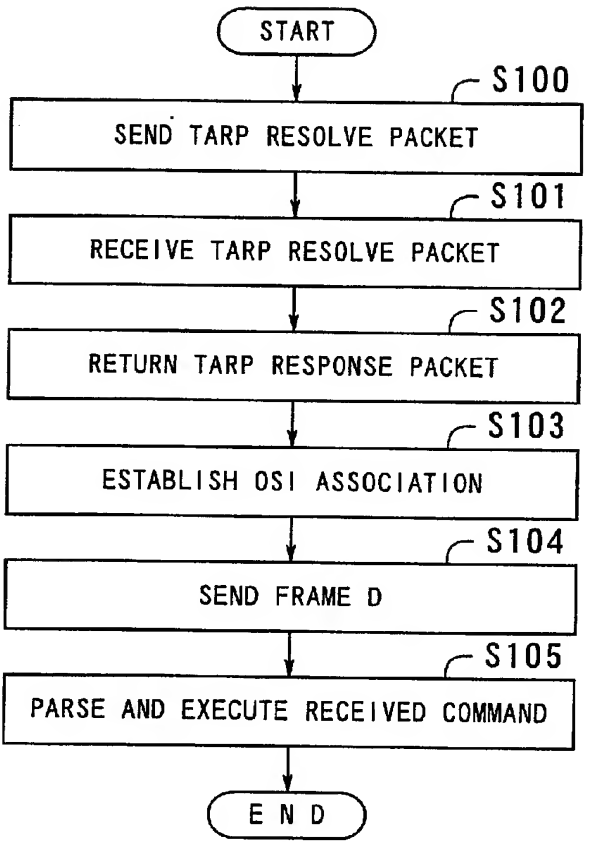

START
S100
SEND TARP RESOLVE PACKET
S101
RECEIVE TARP RESOLVE PACKET
S102
RETURN TARP RESPONSE PACKET
S103
ESTABLISH OSI ASSOCIATION
S104
SEND FRAME D
S105
PARSE AND EXECUTE RECEIVED COMMAND
E N D

FIG. 38

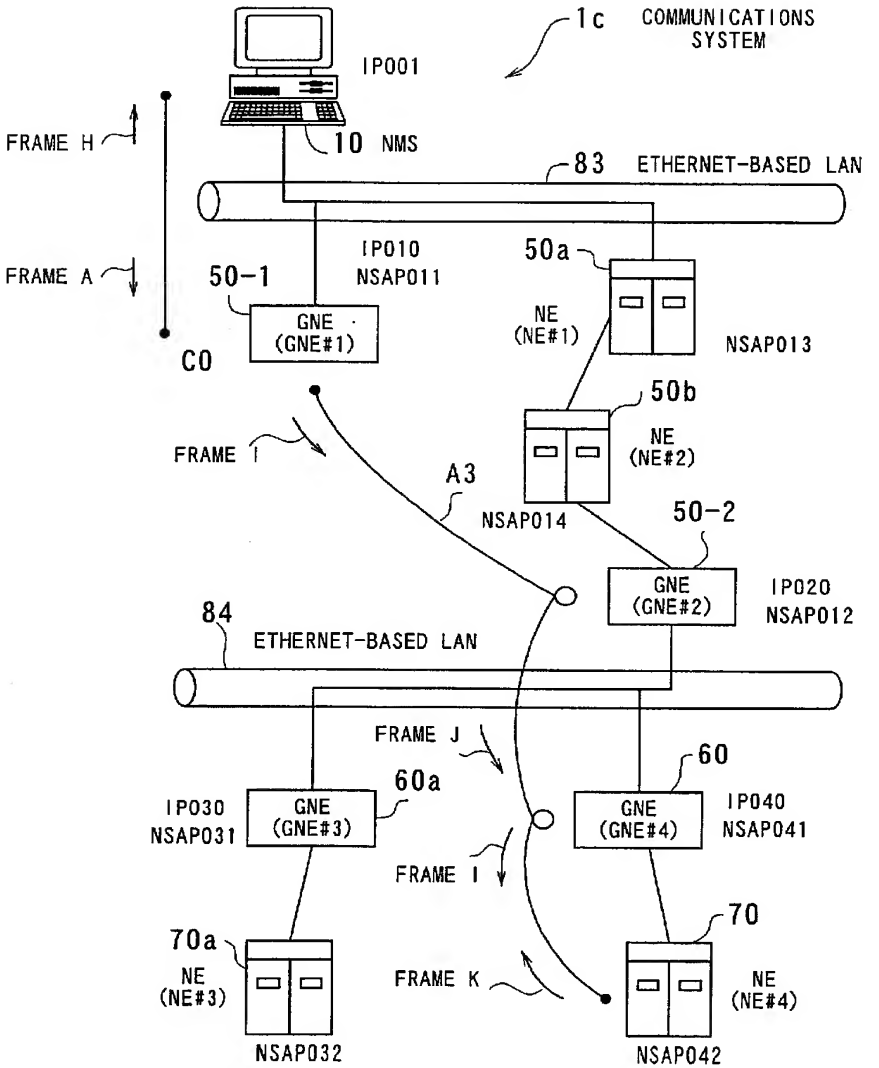

1c
COMMUNICATIONS SYSTEM
IP001
10 NMS
83 ETHERNET-BASED LAN
FRAME H
FRAME A
50-1
IP010
NSAP011
GNE (GNE#1)
C0
50a
NE (NE#1)
NSAP013
50b
NE (NE#2)
FRAME I
A3
NSAP014
50-2
GNE (GNE#2)
IP020
NSAP012
84
ETHERNET-BASED LAN
FRAME J
60
60a
IP030
NSAP031
GNE (GNE#3)
GNE (GNE#4)
IP040
NSAP041
FRAME I
70
70a
NE (NE#3)
FRAME K
NE (NE#4)
NSAP032
NSAP042

FIG. 39

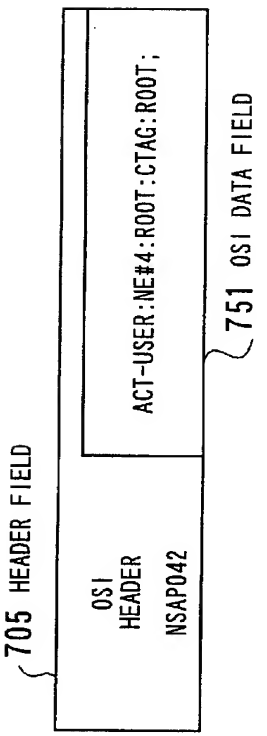



FIG. 40(A)

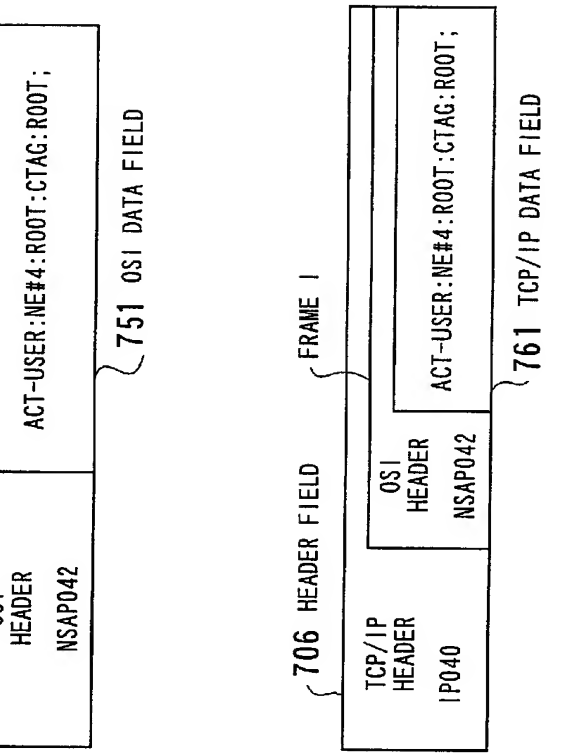



FIG. 40(B)

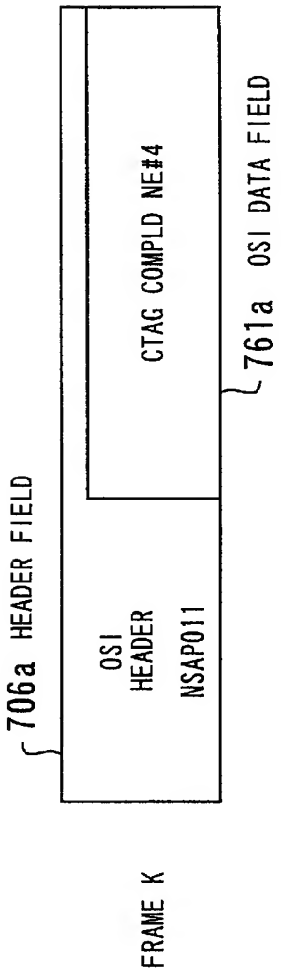

FRAME K
706a HEADER FIELD
OSI
HEADER
NSAP011
CTAG COMPLD NE#4
761a OSI DATA FIELD

FIG. 41

T2

| No | NEIGHBOR'S NSAP ADDRESS |
|---|---|
| 1 | NSAP031 |
| 2 | NSAP041 |

FIG. 42(A)

T3

| No | NSAP ADDRESS PREFIX | IP ADDRESS |
|---|---|---|
| 1 | NSAP03 | IP030 |
| 2 | NSAP04 | IP040 |

FIG. 42(B)

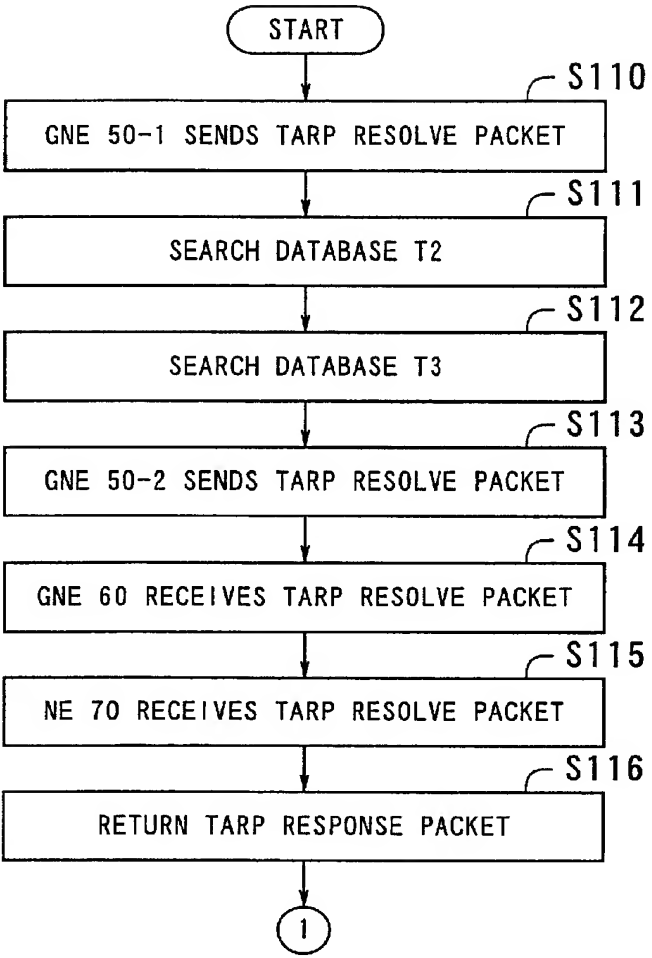

START
S110
GNE 50-1 SENDS TARP RESOLVE PACKET
S111
SEARCH DATABASE T2
S112
SEARCH DATABASE T3
S113
GNE 50-2 SENDS TARP RESOLVE PACKET
S114
GNE 60 RECEIVES TARP RESOLVE PACKET
S115
NE 70 RECEIVES TARP RESOLVE PACKET
S116
RETURN TARP RESPONSE PACKET
1

FIG. 43

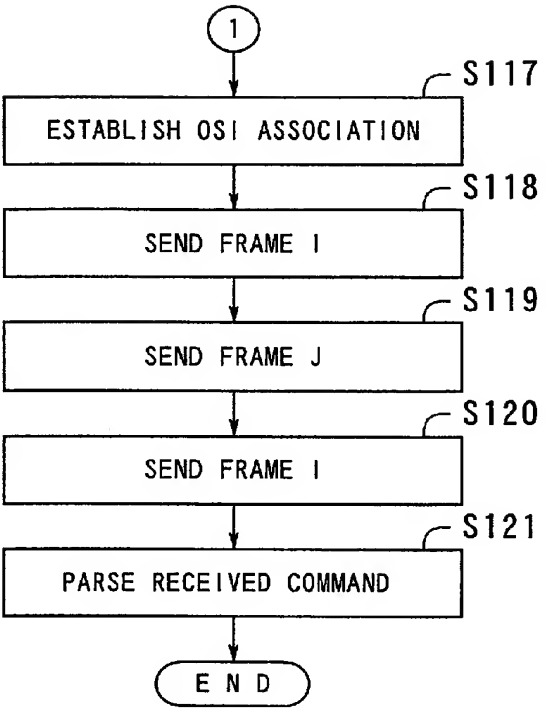

1
S117
ESTABLISH OSI ASSOCIATION
S118
SEND FRAME I
S119
SEND FRAME J
S120
SEND FRAME I
S121
PARSE RECEIVED COMMAND
E N D

FIG. 44

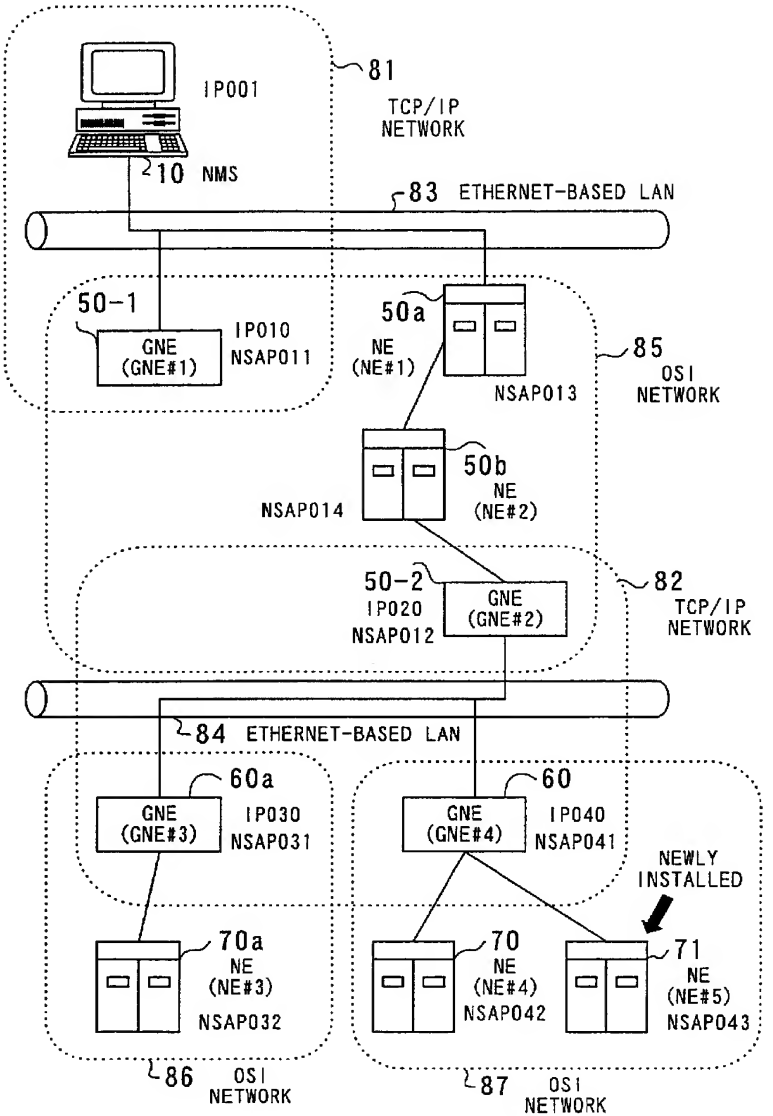

81
IP001
TCP/IP
NETWORK
10 NMS
83 ETHERNET-BASED LAN
50-1
GNE
(GNE#1)
IP010
NSAP011
50a
NE
(NE#1)
NSAP013
85
OSI
NETWORK
50b
NE
(NE#2)
NSAP014
50-2
IP020
NSAP012
GNE
(GNE#2)
82
TCP/IP
NETWORK
84 ETHERNET-BASED LAN
60a
GNE
(GNE#3)
IP030
NSAP031
60
GNE
(GNE#4)
IP040
NSAP041
NEWLY
INSTALLED
70a
NE
(NE#3)
NSAP032
70
NE
(NE#4)
NSAP042
71
NE
(NE#5)
NSAP043
86 OSI
NETWORK
87 OSI
NETWORK

FIG. 45

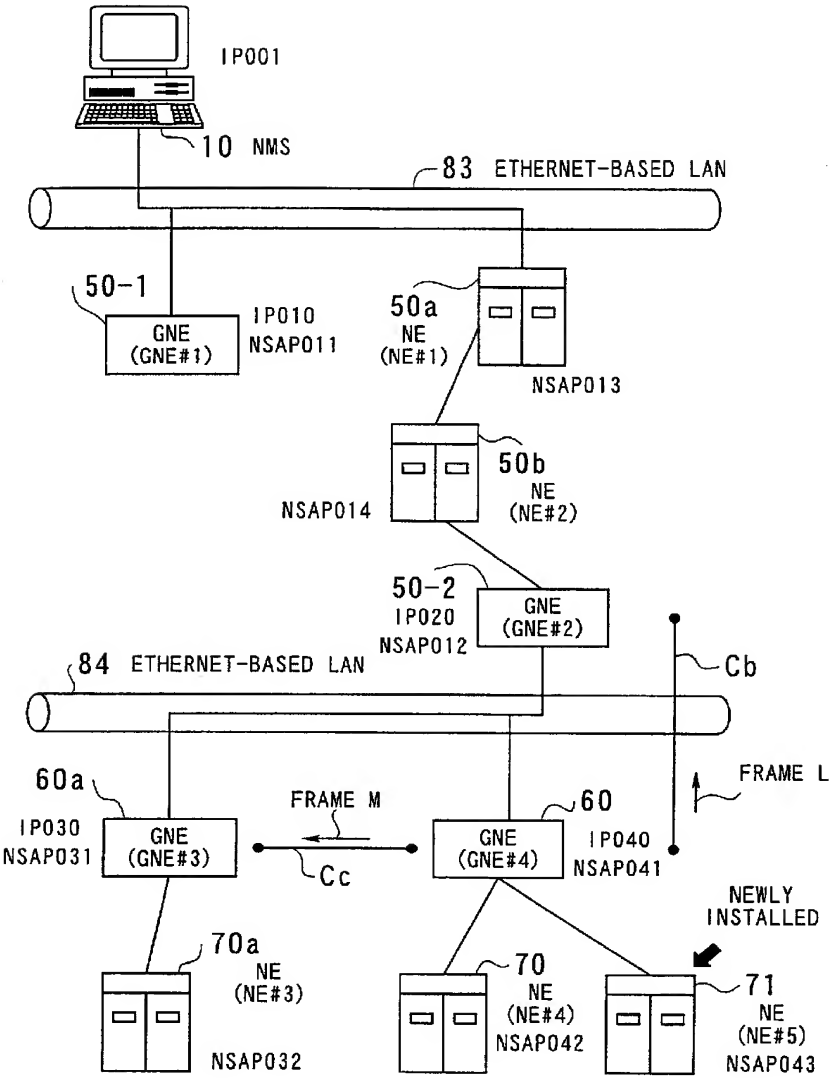

IP001
10 NMS
83 ETHERNET-BASED LAN
50-1
GNE
(GNE#1)
IP010
NSAP011
50a
NE
(NE#1)
NSAP013
50b
NE
(NE#2)
NSAP014
50-2
IP020
NSAP012
GNE
(GNE#2)
84 ETHERNET-BASED LAN
Cb
60a
IP030
NSAP031
GNE
(GNE#3)
FRAME M
Cc
60
GNE
(GNE#4)
IP040
NSAP041
FRAME L
NEWLY
INSTALLED
70a
NE
(NE#3)
NSAP032
70
NE
(NE#4)
NSAP042
71
NE
(NE#5)
NSAP043

FIG. 46

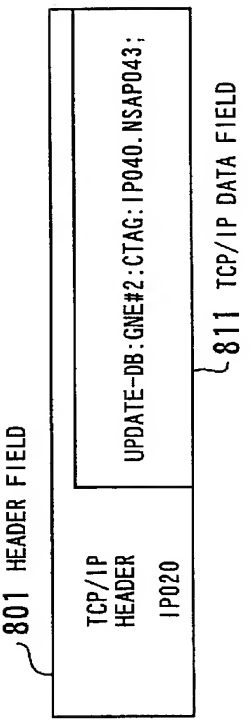



FIG. 47(A)

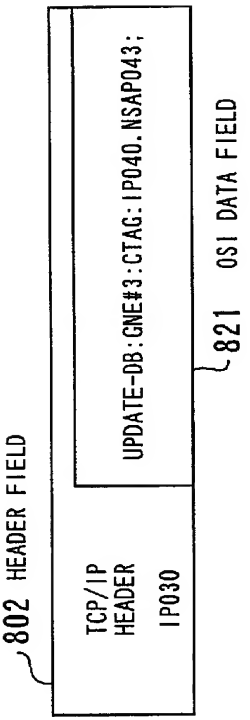



FIG. 47(B)

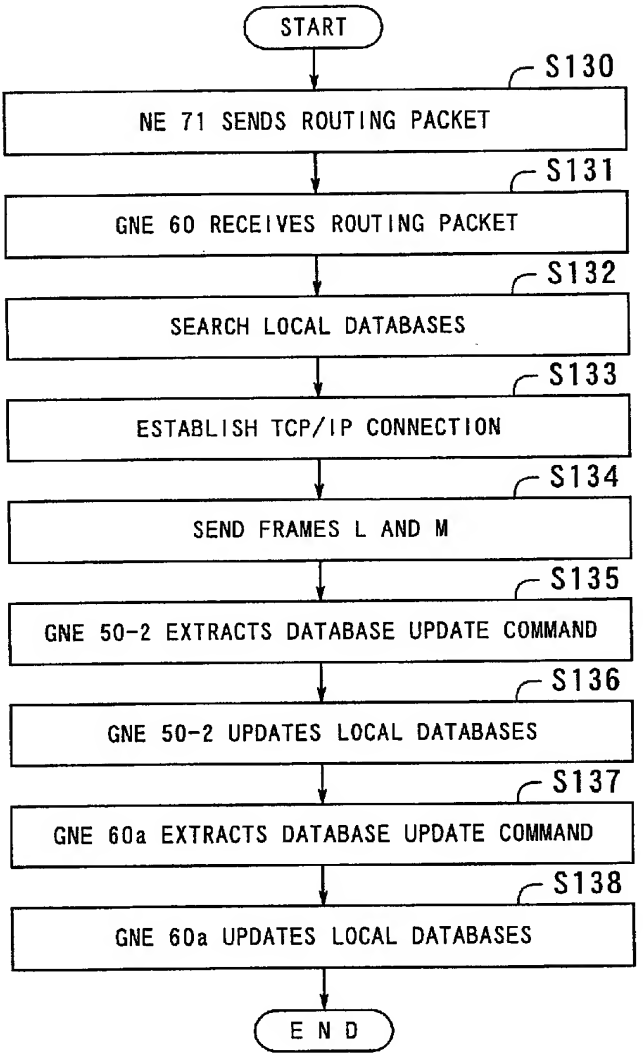

START
S130
NE 71 SENDS ROUTING PACKET
S131
GNE 60 RECEIVES ROUTING PACKET
S132
SEARCH LOCAL DATABASES
S133
ESTABLISH TCP/IP CONNECTION
S134
SEND FRAMES L AND M
S135
GNE 50-2 EXTRACTS DATABASE UPDATE COMMAND
S136
GNE 50-2 UPDATES LOCAL DATABASES
S137
GNE 60a EXTRACTS DATABASE UPDATE COMMAND
S138
GNE 60a UPDATES LOCAL DATABASES
END

FIG. 48

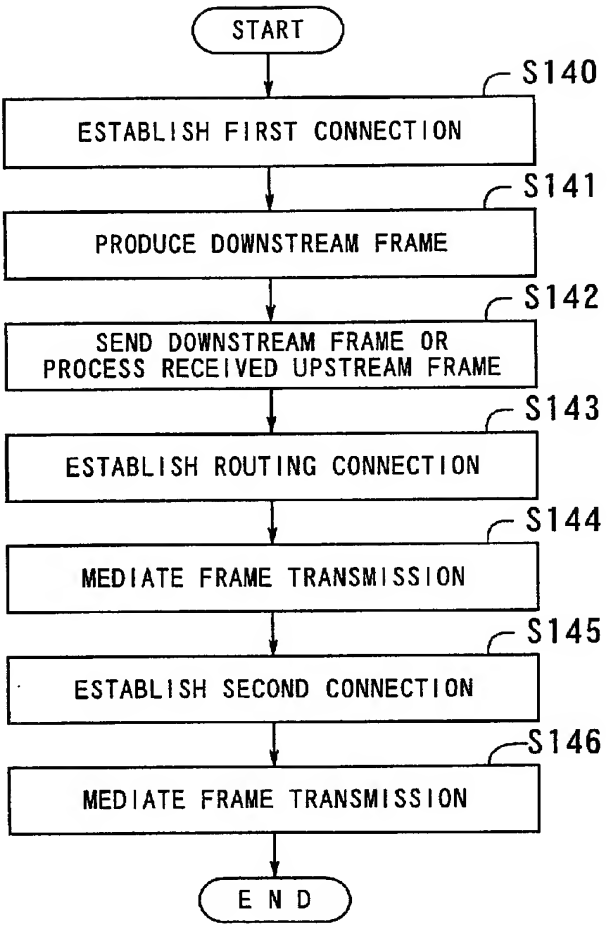
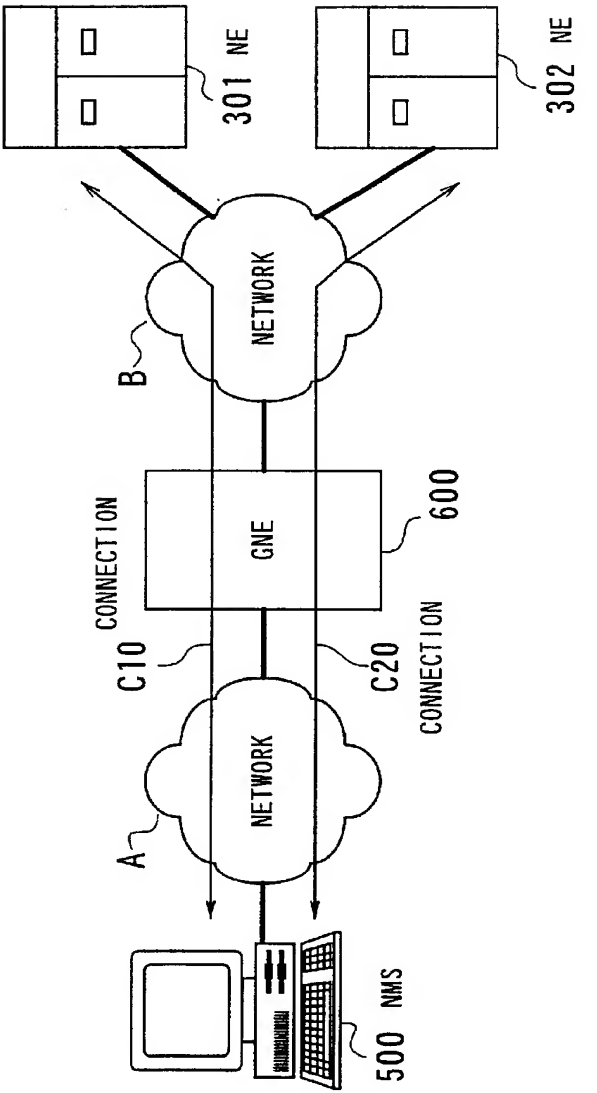
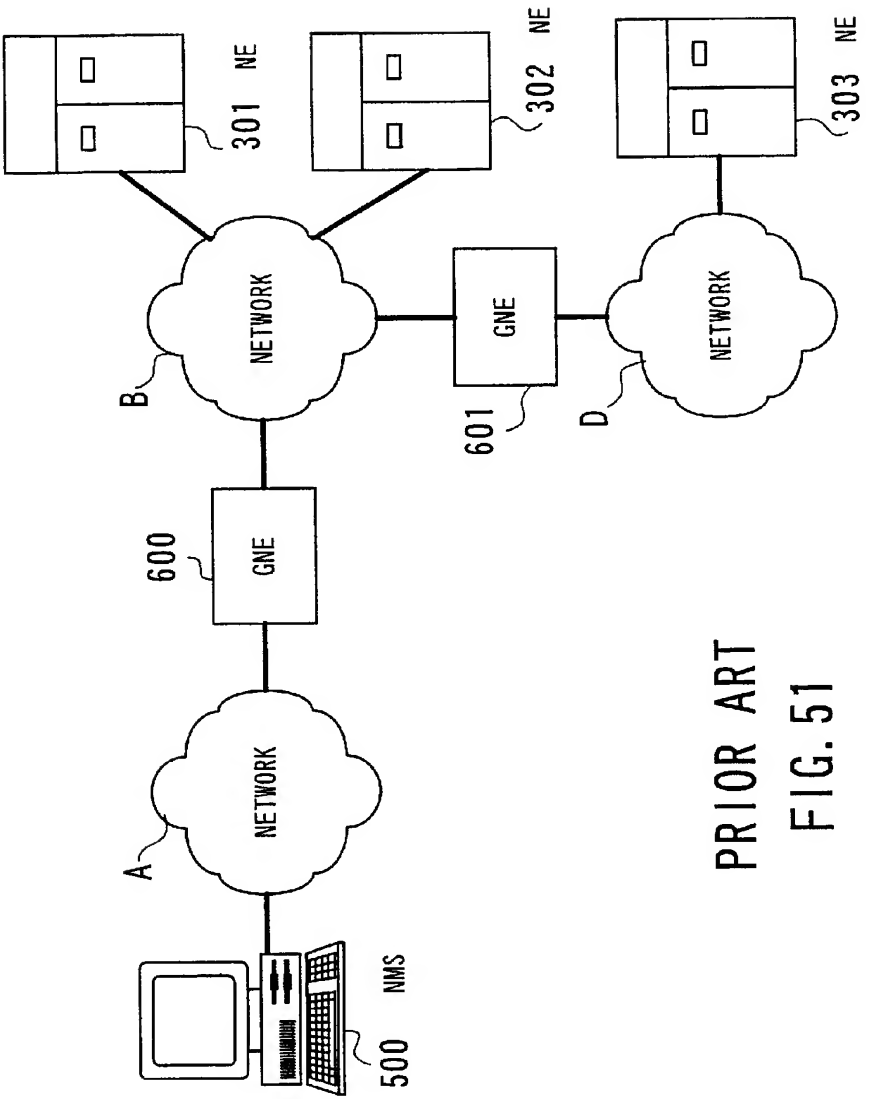

START
S140
ESTABLISH FIRST CONNECTION
S141
PRODUCE DOWNSTREAM FRAME
S142
SEND DOWNSTREAM FRAME OR PROCESS RECEIVED UPSTREAM FRAME
S143
ESTABLISH ROUTING CONNECTION
S144
MEDIATE FRAME TRANSMISSION
S145
ESTABLISH SECOND CONNECTION
S146
MEDIATE FRAME TRANSMISSION
END

FIG. 49




PRIOR ART
FIG. 50




PRIOR ART
FIG. 51

# INTERNETWORKING SYSTEM AND METHOD

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an internetworking system and method, and more particularly to an internetworking system and method for interconnecting a plurality of networks that use different protocols.

2. Description of the Related Art

Today's network systems have increased in size and complexity to serve the diverse user needs for telecommunications services. The proliferation of multi-protocol routers, gateways, and other like devices has become a driving force for interworking between local networks, as opposed to isolated networks in the past. This also promotes the rapid development of heterogeneous network environments where dissimilar protocols are used together. In order to monitor and control such a sophisticated environment, many of conventional network management systems deploy a dedicated network management station (NMS) for each individual network. In recent years, however, there is an increasing demand for more efficient network management systems which can supervise network elements (NEs) deployed over different networks in. a centralized manner.

The Japanese Unexamined Patent Application Publication No. 10-327152 (1998) is one example of conventional network management techniques. According to this publication, a network management system employs all kinds of necessary protocol stacks, thereby supervising the entire network environment using different protocols.

FIG. **50** shows a conventional network management system. In this system, an NMS **500** is coupled to a network A, and NEs **301** and **302** are located on another network B, where the two networks A and B use different communication protocols. A gateway network element (GNE) **600** is interposed between the networks A and B to provide network mediation services to control internetworking processes between them.

To illustrate how the network B is managed, it is assumed here that the NMS **500** now intends to access the remote NE **301**. Having a lower-layer protocol stack of the network B being monitored, the NMS **500** produces a header that complies with the protocol specifications used in the network B. Since the network A, on the other hand, has its own frame format, the NMS **500** inserts the above header to the data field of a frame for the network A to which the NMS **500** belongs to. In this way, the NMS **500** creates a hybrid frame containing information about both protocols. After setting up a connection C**10** to reach the NE **301** via the GNE **600**, the NMS **500** sends out the hybrid frame.

The above-described technique enables the NMS **500** to have an end-to-end access to the NE **301** located on the network B, whose protocol is different from the network A's. The NMS **500** can communicate with the other remote NE **302** in a similar way. That is, the NMS **500** asks the GNE **600** to establish a connection C**20** extending to the NE **302**, creates a like hybrid frame, and sends it toward the NE **302**.

Such conventional internetworking techniques, however, have the following disadvantages. First, it requires the NMS **500** to set up a dedicated connection to every destination NE, which produces a number of connections at a time. This naturally causes increased traffic and consequent slow access to a plurality of NEs.



Second, in the conventional internetworking system, the NMS **500** has to create a hybrid frame containing information about both protocols used in the networks A and B, when transporting data in this heterogeneous environment. Such a construct of hybrid frames may result in a large amount of data to be transmitted over the networks, thus causing a substantial increase in the network traffic.

Third, the conventional internetworking system is quite limited in its service coverage area. Actually, the NMS **500** only covers its local network A and its neighboring network B, which is immediately adjacent to the network A. FIG. **51** shows another conventional system which consists of three networks A, B, and D whose protocols are different from one another. The network D is linked with the network B via a GNE **601**, and an NE **303** is located on this network D. In such a conventional system, the NMS **500** is unable to monitor the network D, because it is not directly linked with the network A, where the NMS **500** resides. The problem is that the NMS **500** cannot resolve the address of the NE **303** on the network D, since the network D and its neighboring network B do not share their address resolution protocols. For this reason, the NMS **500** cannot communicate with the NE **303**.

## SUMMARY OF THE INVENTION

Taking the above into consideration, an object of the present invention is to provide an internetworking system which efficiently interconnects heterogeneous networks by mediating between different protocols.

Another object of the present invention is to provide an internetworking method which efficiently interconnects heterogeneous networks by mediating between different protocols.

To accomplish the first object note above, according to the present invention, there is provided an internetworking system for interconnecting a plurality of networks that use different protocols. This internetworking system comprises a network management station and a mediation device. The network management station comprises the following elements:

- a first connection setting unit which establishes a first connection over a first network in a point-to-point fashion;
- a downstream frame generator which produces a downstream frame containing an identifier of a network element that the network management station intends to interact with, wherein the network element being on a second network whose communication protocol is different from that of the first network; and
- a frame communication unit which sends out the downstream frame through the first connection, and/or processes an upstream frame received through the first connection.

The mediation device, on the other hand, comprises the following elements:

- a second connection setting unit which establishes a second connection in a point-to-point or point-to-multipoint fashion over the second network to reach the network element; and
- a frame mediation unit which receives the downstream frame through the first connection and forwards the received downstream frame to the network element through the second connection, or receives an upstream frame from the network element through the second connection and forwards the received upstream frame to the network management station through the first connection.

Further, to accomplish the second object note above, the present invention provides an internetworking method for interconnecting heterogeneous network environments that use different protocols. This internetworking method comprises the following steps:

(a) establishing a first connection over a first network in a point-to-point fashion;

(b) producing a downstream frame containing an identifier of a network element that is to be reached, the network element being on a second network whose communication protocol is different from that of the first network;

(c) sending out the downstream frame through the first connection, or processing an upstream frame received through the first connection;

(d) establishing a second connection in a point-to-point or point-to-multipoint fashion over the second network to reach the network element; and

(e) receiving the downstream frame through the first connection and forwarding the received downstream frame to the network element through the second connection, or receiving an upstream frame from the network element through the second connection and forwarding the received upstream frame through the first connection.

The above and other objects, features and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a conceptual view of an internetworking system according to the present invention.

FIG. **2**(A) is a diagram which shows the structure of downstream frames flowing over a connection between NMS and GNE;

FIG. **2**(B) is a diagram which shows the structure of upstream frames flowing over a connection between NMS and GNE;

FIG. **3**(A) is a diagram which shows the structure of downstream frames flowing over a connection between GNE and NE;

FIG. **3**(B) is a diagram which shows the structure of upstream frames flowing over a connection between GNE and NE;

FIG. **4**(A) is a diagram which shows the structure of downstream frames flowing over a connection between GNE and NE;

FIG. **4**(B) is a diagram which shows the structure of upstream frames flowing over a connection between GNE and NE;

FIG. **5**(A) is a diagram which shows the structure of downstream frames flowing over a connection between GNE and NE;

FIG. **5**(B) is a diagram which shows the structure of upstream frames flowing over a connection between GNE and NE;

FIG. **6** is a diagram which shows an example of a connection database;

FIGS. **7** to **10** are diagrams which show various communication protocol models;

FIG. **11** is a diagram showing the structure of a communications system where the present invention is implemented;

FIG. **12** is a diagram showing a situation where a TCP/IP connection and OSI associations have been established;

FIG. **13** is a diagram which shows a connection database;

FIG. **14** is a flowchart which shows how a frame A is sent from NMS to GNE;

FIG. **15** is a flowchart which shows how frames B and C are exchanged between GNE and NE;

FIG. **16** is a flowchart which shows how frames D and E are exchanged between GNE and NE;

FIG. **17** is a flowchart which shows how frames F and G are exchanged between GNE and NE;

FIG. **18** is a flowchart which shows how frames H, I, J, and K are sent from GNE to NMS;

FIG. **19** is a flowchart which shows how the NMS receives frames H, I, J, and K;

FIG. **20** is a diagram which shows the structure of a frame A;

FIG. **21**(A) is a diagram which shows the structure of a frame B;

FIG. **21**(B) is a diagram which shows the structure of a frame C;

FIG. **22**(A) is a diagram which shows the structure of a frame D;

FIG. **22**(B) is a diagram which shows the structure of a frame E;

FIG. **23**(A) is a diagram which shows the structure of a frame F;

FIG. **23**(B) is a diagram which shows the structure of a frame G;

FIG. **24**(A) is a diagram which shows the structure of a frame H;

FIG. **24**(B) is a diagram which shows the structure of a frame I;

FIG. **25**(A) is a diagram which shows the structure of a frame J;

FIG. **25**(B) is a diagram which shows the structure of a frame K;.

FIG. **26** is a flowchart which shows an internetworking method according to the present invention;

FIG. **27** is a conceptual view of another internetworking system according to the present invention;

FIG. **28** is a diagram showing the structure of another communications system where the present invention is implemented;

FIG. **29** is a diagram showing a situation where several TCP/IP connections and OSI associations have been established;

FIG. **30**(A) is a diagram which shows the structure of a frame A;

FIG. **30**(B) is a diagram which shows the structure of a frame B;

FIG. **31**(A) is a diagram which shows the structure of a frame C;

FIG. **31**(B) is a diagram which shows the structure of a frame D;

FIG. **32**(A) is a diagram which shows the structure of a frame E;

FIG. **32**(B) is a diagram which shows the structure of a frame F;

FIG. **33**(A) is a diagram which shows the structure of a frame G;

FIG. **33**(B) is a diagram which shows the structure of a frame H;

FIG. **34** is a diagram which shows a database;

FIG. **35** is a flowchart which shows how a frame A is sent from NMS to GNE;

FIG. **36** is a flowchart which shows how a frame B is sent from one GNE to another GNE;

FIG. **37** is a flowchart which shows how a frame C is sent from one GNE to another GNE;

FIG. **38** is a flowchart which shows how frame D are sent from GNE to NE;

FIG. **39** is a diagram showing a situation where one TCP/IP connection and one OSI association have been established in a modified communications system;

FIG. **40**(A) is a diagram which shows the structure of a frame I;

FIG. **40**(B) is a diagram which shows the structure of a frame J;

FIG. **41** is a diagram which shows the structure of a frame K;

FIGS. **42**(A) and **42**(B) are diagrams which show databases;

FIGS. **43** and **44** show a flowchart describing how frames I and J are sent from GNE to NE;

FIG. **45** is a diagram showing a situation where one NE has been newly added to the system;

FIG. **46** is a diagram which shows a situation where several TCP/IP connections have been established;

FIG. **47**(A) is a diagram which shows the structure of a frame L;

FIG. **47**(B) is a diagram which shows the structure of a frame M;

FIG. **48** is a flowchart which shows a process to update a database automatically;

FIG. **49** is a flowchart which shows another internetworking method according to the present invention;

FIG. **50** is a diagram which shows a conventional network management system; and

FIG. **51** is a diagram which shows a system consisting of three networks using different protocols.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will be described below, with reference to the accompanying drawings.

FIG. **1** is a conceptual view of an internetworking system according to the present invention. This internetworking system **1** comprises a network management station (NMS) **10**, a gateway network element (GNE) **20**, and three network elements (NEs) **30-1** to **30-3**. The GNE **20** acts as a mediation device which provides mediation services to interconnect other network nodes. While FIG. **1** shows only three NEs, any number of network elements can be connected to the GNE **20** via the illustrated networks or any other networks that use different protocols.

The NMS **10** and GNE **20** are linked via a network A using a communication protocol La. The GNE **20** is also connected to the NEs **30-1** to **30-3** via other networks that use dissimilar protocols other than the communication protocol La. More specifically, FIG. **1** shows that the GNE **20** is linked to the NEs **30-1** and **30-2** via a network B with a communication protocol Lb that differs from La. Further, the GNE **20** reaches the NE **30-3** through a network C with a communication protocol Lc that differs from the others. For illustrative purposes, it is assumed that the network A employs TCP/IP as its communication protocol La. It is also assumed that the network B uses TP4/CLNP as its communication protocol Lb, and the network C adopts X.25 as its communication protocol Lc.

The NMS **10** comprises a first connection setting unit **11**, a downstream frame generator **12**, and a frame communication unit **13**. The first connection setting unit **11** establishes a point-to-point connection C**0** between the NMS **10** and GNE **20** over the network A. This connection C**0** is referred to herein as the "first connection." In the present invention, the term "connection" is used to mean either (1) a logical connection path established for end-to-end communication over the transport layer, or the layer **4**, defined in the Open Systems Interconnection (OSI) reference model, or (2) an association (i.e., logical connection path) established for peer-to-peer communication at the application layer defined in the same model.

The downstream frame generator **12** produces a downstream frame Df**0** containing the identifiers of NEs to which the frame is directed. Note here that it can insert to each frame Df**0** a plurality of identifiers corresponding to a plurality of destination NEs. Consider, for instance, that the NMS **10** has some data to send to remote NEs **30-1**, **30-2**, and **30-3**. In this case, the downstream frame generator **12** produces a single downstream frame Df**0** having the following three identifiers: NE#1 for NE **30-1**, NE#2 for NE **30-2**, and NE#3 for NE **30-3**. The frame communication unit **13** transmits this downstream frame Df**0** to the GNE **20** through the connection C**0**. It may also receive an upstream frame UfO that the GNE **20** mediated to the NMS **10** through the connection C**0**. As seen from the above, the message frames sent from the NMS **10** to remote NEs through the GNE **20** are called the "downstream frames" in the present invention. On the other hand, the term "upstream frames" refers to the message frames transported in the opposite direction, from remote NEs to the NMS **10** via the GNE **20**.

The GNE **20** comprises a second connection setting unit **21** and a frame mediation unit **22**. When a downstream frame Df**0** is received, the second connection setting unit **21** finds destination identifiers in the frame Df**0** and establishes a second connection to reach the relevant NEs that are determined by the identifiers. In the current example, the second connection setting unit **21** obtains three identifiers NE#1, NE#2, and NE#3 from the received downstream frame Df**0**. Therefore, it sets up a point-to-multipoint connection involving three connections C**1**, C**2**, and C**3** between the GNE **20** and NEs **30-1**, **30-2**, and **30-3**, respectively. If the downstream frame Df**0** contained only one NE identifier, the second connection setting unit **21** would establish a single point-to-point connection. Such point-to-point or point-to-multipoint connections produced by the second connection setting unit **21** are referred to herein as the "second connection."

The frame mediation unit **22** mediates the transmission of downstream frames to the NEs through the second connection established between the GNE **20** and NEs, when those frames are addressed to the NEs. In the present example, three downstream frames Df**1**, Df**2**, and Df**3** addressed to the NEs **30-1**, **30-2**, and **30-3** are forwarded to their respective destinations through the connections C**1**, C**2**, and C**3**. Generally, the frame mediation unit **22** also mediates the reception of upstream frames by receiving such frames from remote NEs through the pre-established connections and then forwarding them to the NMS **10**, which is serving as an upstream device of those NEs. In the present example, it

receives upstream frames Uf1, Uf2, and Uf3 from the NEs 30-1, 30-2, and 30-3 through the connections C1, C2, and C3 and forwards them to the NMS 10. The frame mediation unit 22 converts between different protocols with reference to its local connection database (described later) during the process of network mediation control.

According to the above-described invention, the internetworking system 1 is configured to establish a point-to-point connection C0 between the NMS 10 and GNE 20, together with a point-to-multipoint connection C1 to C3 between the GNE 20 and NEs 30-1 to 30-3. These connections will form a point-to-multipoint (1:N) connection extending from the NMS 10 to the NEs 30-1 to 30-*n*. As previously discussed in FIG. 50, the conventional network management system requires the NMS to establish a 1:1 connection for each intended NE when attempting to access remote NEs for supervisory purposes. In contrast to this, the present invention permits the NMS to set up a more efficient 1:N connection to reach the NEs, through the use of the GNE 20's mediation services. This configuration liberates the NMS 10 from the tasks of managing a plurality of connections. That is, the NMS 10 only has to set up a single connection to communicate with a plurality of remote NEs.

Another advantage of the invention is its simplified frame structure. In conventional systems, the NMS should create frames with relatively large additional data to meet the specifications of different protocols used in a remote network that interconnects a GNE and NE. As opposed to this, the present invention minimizes the amount of that additional data; the NMS only has to supply information related to the application layer. This reduces the size of each frame, thus alleviating the load on the network traffic. Furthermore, the NMS 10 can send a frame that is addressed to a plurality of NEs at a time. This feature improves the network performance, providing an increased access speed when the NMS 10 interact with remote NEs.

Referring now to FIGS. 2(A) to 5(B), the structures of downstream and upstream frames will be described in more detail below, assuming their use in the internetworking system 1 of FIG. 1.

FIGS. 2(A) and 2(B) show the structure of downstream frames Df0 and upstream frames Uf0 flowing over the connection C0 between the NMS 10 and GNE 20. Those downstream frame Df0 and upstream frame Uf0 each comprise a header field and a data field that conform to the communication protocol La used in the network A.

The general structure of downstream frames Df0 is as follows. Its header field 101 contains the destination address information (identifiers) 101-1, which specifies the GNE 20, connection C0, and the like in this case. The data field 111 carries a plurality of packets P1 to P3. Packet P1 is a packet directed to the NE 30-1, containing an identifier TID1 ("NE#1") of and command Cm1 to the NE 30-1. Packet P2 is a packet directed to the NE 30-2, containing an identifier TID2 ("NE#2") of and command Cm2 to the NE 30-2. Packet P3 is a packet directed to the NE 30-3, containing an identifier TID3 ("NE#3") of and command Cm3 to the NE 30-3.

Upstream frames Uf0, on the other hand, have the following structure. Their header section 101*a* contains destination address information (identifiers) 101*a*-1, which specifies the NMS 10 and connection C0 in this case. The data field 111*a* carries a plurality of packets P1*a* to P3*a*. Packet P1*a* is a packet returned from the NE 30-1, containing an identifier TID1 ("NE#1") of and response Re1 from the NE 30-1. Packet P2*a* is a packet returned from the NE 30-2, containing an identifier TID2 ("NE#2") of and response Re2 from the NE 30-2. Packet P3*a* is a packet returned from the NE 30-3, containing an identifier TID3 ("NE#3") of and response Re3 from the NE 30-3.

FIGS. 3(A) and 3(B) show the structures of downstream frames Df1 and upstream frames Uf1 flowing over the connection C1 between the GNE 20 and NE 30-1. Those downstream frames Df1 and upstream frames Uf1 each comprise a header field and a data field that conform to the communication protocol Lb used in the network B.

The structure of downstream frames Df1 is as follows. The header section 201 of a frame contains destination address information (identifiers) 201-1, which specifies the NE 30-1, connection C1, and the like. The data field 211 carries the packet P1, one of the aforementioned downstream packets. Upstream frames Uf1, on the other hand, have the following structure. The header section 201*a* of a frame contains destination address information (identifiers) 201*a*-1, which specifies the GNE 20, connection C1, and so on. The data field 211*a* carries the packet P1*a*, one of the aforementioned upstream packets.

FIGS. 4(A) and 4(B) show the structure of downstream frames Df2 and upstream frames Uf2 flowing over the connection C2 pre-established between the GNE 20 and NE 30-2. Those downstream frames Df2 and upstream frames Uf2 each comprise a header field and a data field that conform to the communication protocol Lb used in the network B.

The structure of downstream frame Df2 is as follows. The header section 202 of a frame contains destination address information (identifiers) 202-1, which specifies the NE 30-2 connection C2, and the like. The data field 221 carries the aforementioned packet P2. Upstream frames Uf2, on the other hand, have the following structure. The header section 202*a* contains destination address information (identifiers) 202*a*-1 which specifies the GNE 20, connection C2, and so on. The data field 221*a* carries one of the aforementioned packets, P2*a*.

FIGS. 5(A) and 5(B) show the structure of downstream frames Df3 and upstream frames Uf3 flowing over the connection C3 between the GNE 20 and NE 30-3. Those downstream frames Df3 and upstream frames Uf3 each comprise a header field and a data field that conform to the communication protocol Lc used in the network C.

The structure of downstream frames Df3 is as follows. The header section 203 of a frame contains destination address information (identifiers) 203-1, which specifies the NE 30-3 and connection C3. The data field 231 carries one of the aforementioned packets, P3. Upstream frames Uf3, on the other hand, have the following structure. The header section 203*a* contains destination address information (identifiers) 203*a*-1 which specifies the GNE 20, connection C3, and so on. The data field 231*a* carries the aforementioned packet P3*a*.

Recall that the conventional hybrid frames contain data of a plurality of protocols. According to the present invention, the downstream and upstream frames are unlike those conventional frames, thus imposing only a smaller load on the network traffic.

When connections are established between the NMS 10 and GNE 20, and between the GNE 20 and NEs 30-1 to 30-3, the GNE 20 stores some records necessary for using those connections into a part of its local memory. This storage is called a connection database. The next section will now focus on the connection database.

FIG. 6 shows a typical connection database 23 whose records describe the connections being established in the

system of FIG. **1**. This connection database **23** stores a plurality of entries, herein called "tables," each having the following data fields: table number, network names, and TID. Here, TID denotes a target identifier being assigned to each NE. More specifically, the table #1 contains the following items:

identifier C**0** of the connection being established on the network A,

identifier C**1** of the connection being established on the network B, and

TID "NE#1" of the NE **30-1** at the far end of the established connection C1.

The table #2 contains the following items:

identifier C**0** of the connection being established on the network A,

identifier C**2** of the connection being established on the network B, and

TID "NE#2" of the NE **30-2** at the far end of the established connection C**2**.

The table #3 contains the following items:

identifier C**0** of the connection being established on the network A,

identifier C**3** of the connection being established on the network C, and

TID "NE#3" of the NE **30-3** at the far end of the established connection C**3**.

In the GNE **20**, the frame mediation unit **22** converts between different protocols, based on the connection database **23**, to handle the received downstream frames and upstream frames. This realizes the mediation between the networks A and B, and between the networks A and C.

The present invention can be applied to various communication protocol models. Referring now to FIGS. **7** to **10**, several examples of such protocol models will be described below. In all systems illustrated in FIGS. **7** to **10**, an NMS **10** is linked with a GNE **20** via a TCP/IP-based network, and the GNE **20** is connected with two NEs **30-4** and **30-5** through an OSI-based network. Further, one connection is established between the NMS **10** and GNE **20**, and two associations has been established between the GNE **20** and NEs **30-4** and **30-5**. The term "association" refers to a logical communication channel, or connection, between application layer entities. In FIGS. **7** to **10**, the lines interconnecting small black circles represent message paths, where each black circle shows that messages are processed at that protocol layer.

FIG. **7** shows which communication protocols are implemented in the NMS **10**'s protocol stack. The NMS **10** uses the Ethernet protocol in its physical layer. Protocols implemented in the data link layer include: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) and Logical Link Control-1 (LLC-1). CSMA/CD is one of the fundamental techniques for Ethernet, which controls signal transmission on a local area network to ensure that there is no conflict between terminals that wish to transmit. LLC sublayer is the upper half of the logical link control layer specified in the IEEE 802.2 standard. LLC-1 supports connectionless data transfer services.

Further, the network layer protocols include: Internet Protocol (IP), Internet Control Message Protocol (ICMP), and Address Resolution Protocol (ARP). IP is a core protocol of TCP/IP networks, providing connectionless services in the network layer. ICMP, part of the IP protocol, handles error conditions in the IP network. ARP provides address resolution services, interpreting each node's logical address (IP address) into its corresponding physical LAN address.

For the transport layer, Transmission Control Protocol (TCP) is implemented. TCP is a connection oriented protocol, which serves as another core protocol in a TCP/IP-based network.

Protocols implemented in the session and presentation layers include: Transaction Language-1 (TL1) and Telecommunication Network Protocol (TELNET). TL1 offers the language for communication between terminals. TELNET is an application protocol to provide virtual terminal capabilities that allow its user to access a remote system. Protocols implemented in the application layer include: TL1 and File Transfer Protocol (FTP). Here, FTP is used in transferring files over a TCP/IP-based network.

FIG. **8** shows which communication protocols are implemented in the GNE **20**'s protocol stack. The GNE **20** uses both Ethernet and Data Communication Channel (DCC) in its physical layer. DCC is a data transfer protocol for monitoring and controlling a network. The protocols implemented in the data link layer are: CSMA/CD, LLC-1, and Link Access Protocol for the D channel (LAPD). LAPD is a protocol used to control the D channels of ISDN links.

The network layer has the following routing control protocols: IP, ICMP, ARP, ES-IS, IS-IS, and CLNP. ES-IS (End System to Intermediate System) Routing Protocol is a protocol that defines how to exchange dynamic routing data between an end system (ES) and an intermediary system (IS). IS-IS (Intermediate System to Intermediate System) Routing Protocol defines a procedure of exchanging dynamic routing information between intermediary systems. CLNP (Connectionless Network Protocol) provides connectionless services.

The transport layer protocols include: TCP, TID Address Resolution Protocol (TARP), and Transaction Processing 4 (TP4). TARP interprets a TID into its corresponding logical address, i.e., Network Service Access Point (NSAP) address. TP is a protocol for transaction processing, and TP4 supports additional functions of data error detection and recovery.

The session layer protocols include: TELNET, TL1, TARP, and X.215/X.225. X.215/X.225, among the X.200 series of ITU-T recommendations, defines services (X.215) and protocols (X.225) in the OSI session layer.

The presentation layer protocols include: TELNET, TL1, TARP, and X.216/X.226. Among the X.200 series of ITU-T recommendations, X.216/X.226 defines services (X.216) and protocols (X.226) in the OSI presentation layer.

The application layer protocols are: FTP, TL1, Association Control Service Element (ACSE), and File Transfer, Access and Management (FTAM). ACSE is a protocol for controlling establishment and release of associations. FTAM is used to transfer files in an OSI network.

FIG. **9** shows which communication protocols are implemented in the NE **30-4**'s protocol stack. The physical layer protocols found in this stack are Ethernet and DCC. The data link layer protocols include: CSMA/CD, LLC-1, and LAPD. The network layer protocols are: CLNP, ES-IS, and IS-IS. The transport layer protocols are: TARP and TP4. The session layer protocols are: TARP, and X.215/X.225. The presentation layer protocols are: TARP and X.216/X.226. The application layer protocols are: TL1, ACSE, and FTAM.

While the above paragraph has described the protocol stack of FIG. **9**, the same can apply to that of the NE **30-5** shown in FIG. **10**. Therefore, the explanation for the protocol stack of FIG. **10** will not be provided here.

The next section will now describe a specific communications system as a typical implementation of the present invention. FIG. **11** shows the structure of a communications system **1***a* according to the present invention. This commu-

nications system **1***a* is a heterogeneous network environment which includes a TCP/IP network **41**, an Ethernet-based LAN **42**, and an OSI network **43**. The TCP/IP network **41** includes an NMS **10** and GNE **20** as its network nodes, and the OSI network **43** includes the GNE **20** and NEs **31** to **33**. The NMS **10** and GNE **20** communicate over the Ethernet-based LAN **42**, as do the GNE **20** and NE **31**. The three NEs **31** to **33** are linked together in a ring topology, through fiber optic cables or other transmission media. In such a network configuration, the NMS **10** supports the TCP/IP protocols, while the NEs **31** to **33** are based on the OSI protocols. The GNE **20**, on the other hand, supports both protocols to mediate the communication between the NMS **10** and NEs **31** to **33** via the Ethernet-based LAN **42**.

The GNE **20** and NEs **31** to **33** have their own TIDs (i.e., GNE#0, NE#1, NE#2, NE#3, respectively), allowing application entities to uniquely identify each of those network elements. They also have network-specific logical addresses. For illustrative purposes, assume that the NMS **10** and GNE **20** on the TCP/IP network **41** have their IP addresses 192.10.56.1 and 192.10.56.2, respectively. Assume further that the GNE **20** and NEs **31** to **33** on the OSI network **43** have their NSAP addresses NSAP000, NSAP001, NSAP002, and NSAP003, respectively.

Suppose here that, in the communications system **1***a*, the NMS **10** sends an ACT-USER command to all NEs on the OSI network **43** (i.e., GNE **20**, NE **31** to **33**) through a single TCP connection. "ACT-USER" is a TL1 command that activates a log-in session of a specified network element. When this command is executed, all NEs returns their C0MPLD responses to the NMS **10**, where "C0MPLD" is a message that is defined in the TL1 standard as an indicator of a response to an ACT-USER command. The following provides more details of the above scenario.

FIG. **12** shows a situation where a TCP/IP connection and OSI associations have been established. More specifically, a TCP/IP connection C0 has been established between the NMS **10** and GNE **20**, and OSI associations A1 to A3 have been established between the GNE **20** and NEs **31** to **33**. It is assumed here that the TCP/IP connection C0 has an identifier PORT#01, and that the OSI associations A1 to A3 have their identifiers SEQ#01 to SEQ#03, respectively.

In the communications system la, the network nodes exchange various frames having different structures, which include the following types. "Frame A" denotes a downstream frame to be sent from the NMS **10** to the GNE **20**. "Frames H, I, J, and K" denote upstream frames to be sent from the GNE **20** to the NMS **10**. "Frame B" denotes a downstream frame to be sent from the GNE **20** to the NE **31**. "Frame C" denotes an upstream frame to be sent from the NE **31** to the GNE **20**. "Frame D" denotes a downstream frame to be sent from the GNE **20** to the NE **32**. "Frame E" denotes an upstream frame to be sent from the NE **32** to the GNE **20**. "Frame F" denotes a downstream frame to be sent from the GNE **20** to the NE **33**. "Frame G" denotes an upstream frame to be sent from the NE **33** to the GNE **20**. The details of each frame structure will be discussed later.

FIG. **13** shows a connection database **23** for the communications system **1***a*. This connection database **23** comprises three tables #1 to #3. The first table #1 contains the following items:

- Identifier PORT#01 of the connection C0 established on the TCP/IP network,
- Identifier SEQ#01 of the association A1 established on the OSI network, and
- TID NE#1 of the NE **31** at the far end of the established association A1.

The second table #2 contains the following items:

- Identifier PORT#01 of the connection C0 established to TCP/IP network,
- Identifier SEQ#02 of the association A2 established on the OSI network, and
- TID NE#2 of the NE **32** at the far end of the established association A2.

The third table #3 contains the following items:

- Identifier PORT#01 of the connection C0 established to TCP/IP network,
- Identifier SEQ#03 of the association A3 established on the OSI network, and
- TID NE#3 of the NE **33** at the far end of the established association A3.

Referring now to the flowchart of FIG. **14**, a process of transmitting a frame A will be described below. The NMS **10** sends a frame A to the GNE **20** according to the following steps.

(S1) The NMS **10** retrieves the GNE **20**'s IP address (192.10.56.2) from its local database.

(S2) According to the TCP/IP protocols, the NMS **10** sets up a TCP connection C0, thereby defining PORT#01 to interface with the GNE **20**. This connection is referred to hereafter by its identifier "PORT#01."

(S3) The NMS **10** assembles a frame A containing the following commands in its data field, and transmits it to the GNE **20** through PORT#01.

- ACT_G.PDU: ACT-USER command with GNE **20**'s TID (GNE#0)
- ACT_1.PDU: ACT-USER command with NE **31**'s TID (NE#1)
- ACT_2.PDU: ACT-USER command with NE **32**'s TID (NE#2)
- ACT_3.PDU: ACT-USER command with NE **33**'s TID (NE#3)

(S4) The GNE **20** receives the above frame A from the NMS **10**. It then extracts the ACT_G.PDU command from TCP/IP data field of the received frame A, thus detecting that the target identifier GNE#0 specified in the command agrees with its own TID. The GNE **20** also examines the other commands (ACT_1.PDU, ACT_2.PDU, and ACT_3.PDU) embedded in the same TCP/IP field, and thus finds their respective TIDs (NE#1, NE#2, and NE#3). it detects that none of those specified identifiers agrees with its own TID (GNE#0).

(S5) As a consequence of step S4, the GNE **20** forwards the ACT_G.PDU command to a relevant application running on itself, thereby initiating a log-in session.

(S6) The GNE20 tries to get NSAP addresses of the destination NEs **31** to **33** on the OSI network **43**, according to TARP.

(S7) Obtaining the NSAP addresses of the NEs **31** to **33**, the GNE **20** stores them in its local cache memory.

Referring next to the flowchart of FIG. **15**, a process of transmitting frames B and C will be described below. The GNE **20** sends a frame B and receives a frame C to/from the NE **31** according to the following steps.

(S10) The GNE **20** obtains the NSAP address of the NE **31** from its local cache memory mentioned in step S7 (FIG. **14**). The GNE **20** then establishes an OSI association A1 to reach the NE **31** according to the OSI protocols. This association will be referred to hereafter by its identifier SEQ#01.

(S11) The GNE **20** enters a record to the connection database **23**. This record, called "table #1," has the following values: PORT#01, SEQ#01, and NE#1.

(S12) The GNE **20** extracts ACT_1.PDU out of the frame A received from the NMS **10** and assembles a frame B by inserting the extracted ACT_1.PDU to its OSI data field. The GNE **20** then sends this frame B to its destination, NE **31**, through the association SEQ#01.

(S13) Receiving the frame B from the GNE **20**, the NE **31** extracts and forwards the ACT_1.PDU command to a relevant application running on itself, thereby initiating a log-in session.

(S14) After the log-in session is completed, the NE **31** produces a frame C by inserting a C0MPLD response message (referred to as COMP_1.PDU) to its OSI data field. The NE **31** returns this frame C to the GNE **20** through the association SEQ#01.

Referring next to the flowchart of FIG. **16**, a process of transmitting frames D and E will be described below. The GNE **20** sends a frame D and receives a frame E to/from the NE **32** according to the following steps.

(S20) The GNE **20** obtains the NSAP address of the NE **32** from its local cache memory mentioned in step S7 (FIG. **14**). The GNE **20** then establishes an OSI association A2 to reach the NE **32** according to the OSI protocols. This association will be referred to hereafter by its identifier SEQ#02.

(S21) The GNE **20** enters a record to its connection database **23**. This record, called "table #2," has the following values: PORT#01, SEQ#02, and NE#2.

(S22) The GNE **20** extracts ACT_2.PDU out of the frame A received from the NMS **10** and assembles a frame D by inserting the extracted ACT_2.PDU to its OSI data field. The GNE **20** then sends this frame D to its destination, NE **32**, through the association SEQ#02.

(S23) Receiving the frame D from the GNE **20**, the NE **32** extracts and forwards the ACT_2.PDU command to a relevant application running on itself, thereby initiating a log-in session.

(S24) After the log-in session is completed, the NE **32** produces a frame E by inserting a C0MPLD response message (COMP_2.PDU) to its OSI data field. The NE **32** returns this frame E to the GNE **20** through the association SEQ#02.

Referring next to the flowchart of FIG. **17**, a process of transmitting frames F and G will be described below. The GNE **20** sends a frame F and receives a frame G to/from the NE **33** according to the following steps.

(S30) The GNE **20** obtains the NSAP address of the NE **33** from its local cache memory mentioned in step S7 (FIG. **14**). The GNE **20** then establishes an OSI association A3 to reach the NE **33** according to the OSI protocols. This association will be referred to hereafter by its identifier SEQ#03.

(S31) The GNE **20** enters a record to the connection database **23**. This record, called "table #3," has the following values: PORT#01, SEQ#03, and NE#3.

(S32) The GNE **20** extracts ACT_3.PDU out of the frame A received from the NMS **10** and assembles a frame F by inserting the extracted ACT_3.PDU to its OSI data field. The GNE **20** then sends this frame F to its destination, NE **33**, through the association SEQ#03.

(S33) Receiving the frame F from the GNE **20**, the NE **33** extracts and forwards the ACT_3.PDU command to a relevant application running on itself, thereby initiating a log-in session.

(S34) After the log-in session is completed, the NE **33** produces a frame G by inserting a C0MPLD response message (COMP_3.PDU) to its OSI data field. The NE **33** returns this frame G to the GNE **20** through the association SEQ#03.

Referring next to the flowchart of FIG. **18**, a process of transmitting frames H, I, J, and K will be described below. The GNE **20** sends these frames back to the NMS **10** according to the following steps.

(S40) Receiving the frame C through SEQ#01, the GNE **20** consults its connection database **23** to find a relevant record (i.e., table). From the table #1, it recognizes that the received frame C should be mediated to PORT#01.

(S41) Receiving the frame E through SEQ#02, the GNE **20** consults its connection database **23** to find a relevant table. From the table #2, it recognizes that the received frame E should be mediated to PORT#01.

(S42) Receiving the frame G through SEQ#03, the GNE **20** consults its connection database **23** to find a relevant table. From the table #3, it recognizes that the received frame G should be mediated to PORT#01.

(S43) When the log-in session at step S5 (FIG. **14**) is completed, the GNE **20** produces a frame H by inserting a C0MPLD message (COMP_G.PDU) into its TCP/IP data field. The GNE **20** then sends out this frame H to the NMS **10**, through the connection PORT#01.

(S44) Regarding the received frame C, the GNE **20** produces a frame I by inserting a COMP_1.PDU message to the TCP/IP data field. The GNE **20** then sends out this frame I to the NMS **10**, through the connection PORT#01 that it has recognized at step S40.

(S45) Regarding the received frame E, the GNE **20** produces a frame J by inserting a COMP_2.PDU message to the TCP/IP data field. The GNE **20** then sends out this frame J to the NMS **10**, through the connection PORT#01 that it has recognized at step S41.

(S46) Regarding the received frame G, the GNE **20** produces a frame K by inserting a COMP_3.PDU message to the TCP/IP data field. The GNE **20** then sends out this frame K to the NMS **10**, through the connection PORT#01 that it has recognized at step S42.

Referring next to the flowchart of FIG. **19**, a process of receiving frames H, I, J, and K will be described below. The NMS **10** receives these frames according to the following steps.

(S50) Receiving the frame H through PORT#01, the NMS **10** examines the TID contained in the received COMP_G.PDU message. From this TID value "GNE#0," the NMS **10** recognizes that the frame H is a response from the GNE **20** to indicate the completion of its log-in session.

(S51) Receiving the frame I through PORT#01, the NMS **10** examines the TID contained in the received COMP_1.PDU message. From this TID value "NE#1," the NMS **10** recognizes that the frame I is a response from the NE **31** to indicate the completion of its log-in session.

(S52) Receiving the frame J through PORT#01, the NMS **10** examines the TID contained in the received COMP_1.PDU message. From this TID value "NE#2," the NMS **10** recognizes that the frame J is a response from the NE **32** to indicate the completion of its log-in session.

(S53) Receiving the frame K through PORT#01, the NMS **10** examines the TID contained in the received COMP_1.PDU message. From this TID value "NE#3," the NMS **10** recognizes that the frame K is a response from the NE **33** to indicate the completion of its log-in session.

Referring next to FIGS. **20** to **25**, the detailed formats of the above described frames will be described below.

First, FIG. **20** shows the structure of frame A. The frame A consists of a header field **301** and a TCP/IP data field **311**. The header field **301** comprises the following sub-fields: Ethernet header, IP header, and TCP header. The IP header

contains "192.10.56.2" as the GNE **20**'s IP address, while the TCP header carries the identifier PORT#01 of the TCP connection **C0** being established between the NMS **10** and GNE **20**. The TCP/IP data field **311** holds the following command information: ACTG.PDU addressed to the GNE **20**, ACT_1.PDU addressed to the NE **31**, ACT_2.PDU addressed to the NE **32**, and ACT_3.PDU addressed to the NE **33**.

FIGS. **21**(A) and **21**(B) show the structures of frames B and C, respectively. Referring first to FIG. **21**(A), the frame B consists of a header field **401** and an OSI data field **411**. The header field **401** comprises the following sub-fields: Ethernet header, CLNP header, and TP4 header. The CLNP header contains "NSAP001" as the NSAP address of the NE **31**, while the TP4 header carries the identifier SEQ#01 of the OSI association **A1** being established between the GNE **20** and NE **31**. The OSI data field **411** holds an ACT_1.PDU command addressed to the NE **31**. Referring to FIG. **21**(B), the frame C consists of a header field **401***a* and an OSI data field **411***a*. The header field **401***a* comprises the following sub-fields: Ethernet header, CLNP header, and TP4 header. The CLNP header contains "NSAP000" as the NSAP address of the GNE **20**, while the TP4 header carries the identifier SEQ#01 of the OSI association **A1** being established between the GNE **20** and NE **31**. The OSI data field **411***a* carries a COMP_1.PDU message addressed to the GNE **20**.

FIGS. **22**(A) and **22**(B) show the structures of frames D and E, respectively. Referring first to FIG. **22**(A), the frame D consists of a header field **402** and an OSI data field **421**. The header field **402** comprises the following sub-fields: Ethernet header, CLNP header, and TP4 header. The CLNP header contains "NSAP002" as the NSAP address of the NE **32**, while the TP4 header carries the identifier SEQ#02 of the OSI association A2 being established between the GNE **20** and NE **32**. The OSI data field **421** carries an ACT_2.PDU command addressed to the NE **32**. Referring to FIG. **22**(B), the frame E consists of a header field **402***a* and an OSI data field **421***a*. The header field **402***a* comprises the following multiple sub-fields: Ethernet header, CLNP header, and TP4 header. The CLNP header contains "NSAP000" as the NSAP address of the GNE **20**, while the TP4 header carries the identifier SEQ#02 of the OSI association **A2** being established between the GNE **20** and NE **32**. The OSI data field **421***a* carries a COMP_2.PDU message addressed to the GNE **20**.

FIGS. **23**(A) and **23**(B) show the structures of frames F and G, respectively. Ref erring first to FIG. **23**(A), the frame F consists of a header field **403** and an OSI data field **431**. The header field **403** comprises the following multiple sub-fields: Ethernet header, CLNP header, and TP4 header. The CLNP header contains "NSAP003" as the NSAP address of the NE **33**, while the TP4 header carries the identifier SEQ#03 of the OSI association **A3** being established between the GNE **20** and NE **33**. The OSI data field **431** carries an ACT_3.PDU command addressed to the NE **33**. Referring to FIG. **23**(B), the frame G consists of a header field **403***a* and an OSI data field **431***a*. The header field **403***a* comprises the following multiple sub-fields: Ethernet header, CLNP header, and TP4 header. The CLNP header contains "NSAP000" as the NSAP address of the GNE **20**, while the TP4 header carries the identifier SEQ#03 of the OSI association **A3** being established between the GNE **20** and NE **33**. The OSI data field **431***a* carries a COMP_3.PDU message addressed to the GNE **20**.

FIGS. **24**(A) and **24**(B) show the structures of frames H and I, respectively. Referring first to FIG. **24**(A), the frame H consists of a header field **301***a* and a TCP/IP data field **311***a*-**1**. The header field **301***a* comprises the following multiple sub-fields: Ethernet header, IP header, and TCP header. The IP header contains "192.10.56.1" as the IP address of the NMS **10**, while the TCP header carries the identifier PORT#01 of the TCP connection **C0** being established between the NMS **10** and GNE **20**. The TCP/IP data field **311***a*-**1** carries a COMP_G.PDU message addressed to the NMS **10**. Referring to FIG. **24**(B), each frame I consists of a header field **301***a* (as in the above-described frame H) and a TCP/IP data field **311***a*-**2**. The TCP/IP data field **311***a*-**2** carries a COMP_1.PDU message addressed to the NMS **10**.

FIGS. **25**(A) and **25**(B) show the structures of frames J and K, respectively. Referring first to FIG. **25**(A), the frame J consists of a header field **301***a* and a TCP/IP data field **311***a*-**3**. The TCP/IP data field **311***a*-**3** carries a COMP_2.PDU message addressed to the NMS **10**. Referring to FIG. **25**(B), each frame K consists of a header field **301***a* and a TCP/IP data field **311***a*-**4**. The TCP/IP data field **311***a*-**4** carries a COMP_3.PDU message addressed to the NMS **10**.

While the above section has discussed the internetworking system, the following section will now present an internetworking method according to the present invention. FIG. **26** is a flowchart which shows how the proposed method will be executed. It is assumed here that a network management station (NMS) and a gateway network element (GNE) are on a first network, and the GNE is linked with at least one network element (NE) over a second network. The first and second networks use different communication protocols. The proposed internetworking method comprises the following steps.

(**S60**) A first connection is established in the first network. This first connection is a point-to-point (P-P) connection which links the NMS with the GNE.

(**S61**) The NMS produces a downstream frame containing the identifier of an NE to be reached.

(**S62**) The NMS transmits a downstream frame through the first connection. The NMS also processes upstream frames received from the GNE through the first connection.

(**S63**) The GNE establishes a second connection on the second network to reach the NE that is specified by the identifier. This second connection is either a point-to-point or a point-to-multipoint (P-MP) connection.

(**S64**) The GNE mediates the transmission of the produced downstream frame to the NE through the second connection. The GNE also receives upstream frames from the NE through the second connection and forwards them to the upstream device, thereby mediating upstream transmission.

To make the above processing possible, the GNE employs a connection database which records at least one of the following items: the identifier of the first connection, the identifier of the second connection, and the identifier of the target NE. Based on this connection database, the GNE translates different protocols of the first and second networks, thereby mediating between those networks.

As described thus far, the internetworking system **1** and internetworking method realize the communication between an NMS **10** and remote NEs on a different network by interposing a GNE **20** with enhanced features according to the invention. Since this GNE **20** provides network mediation functions, the NMS **10** need not to coordinate other mediation devices for remote access. Another advantage of the present invention is that it does not require any changes in the protocols implemented in the NMS **10** and individual

NEs. Still another advantage of the invention is that the NMS **10** only has to set up a single connection, even when it communicates with a plurality of remote NEs on a plurality of networks. That is, the NMS **10** can send such a frame that is addressed to a plurality of NEs at a time, without the need for troublesome management of multiple connections. This feature will contribute to improved network performance.

The next section will now describe an internetworking system **100**, another embodiment of the present invention. Unlike the internetworking system **1**, which mediates between two networks using different protocols, this system **100** enables a network management station to communicate with a remote network element beyond two or more incompatible networks.

FIG. **27** provides a conceptual view of the internetworking system **100** according to the present invention. This system **100** comprises: a network management station (NMS) **10**; a gateway network element (GNE) **60** serving as a first mediation device; a network element (NE) **70** which is linked to the GNE **60** and reachable from the NMS **10**; and a plurality of GNEs **50-1** to **50-***n* serving as second mediation devices. The NMS **10** provides the same functions as described earlier in FIG. **1**. While FIG. **27** shows only one NE, any number of network elements can be connected to the GNE **60** or intermediary GNEs **50-1** to **50-***n*.

The NMS **10** and GNE **50-1** are interconnected via a network N1. The GNEs **50-1** to **50-***n* are linked in series via networks N2 to Nn-1. Further, the last GNE **50-***n* is connected to the GNE **60** through a network Nn. The protocols used in the networks N1 to Nn may be different from each other, or some of them may be the same. Although all network elements are arranged in a linear topology in the system of FIG. **27**, it is not intended to limit the preferred embodiment to this particular topology.

As FIG. **27** shows, the GNE **60** comprises a second connection setting unit **61** and a first frame mediation unit **62**. The second connection setting unit **61** sets up a point-to-point connection Ca (second connection) extending to the NE **70**. (If the NMS **10** has to interact with two or more like NEs in the neighborhood of the GNE **60**, the second connection setting unit **61** will establish a point-to-multipoint connection, instead of a point-to-point connection.) The first frame mediation unit **62** mediates the transport of downstream and upstream frames through the connection Ca.

On the other hand, each of the GNEs **50-1** to **50-***n* has a routing connection setting unit **51** and a second frame mediation unit **52**. With their routing control capability, the routing connection setting units **51** establish routing connections C1 to Cn-1 toward the GNE **60**. The second frame mediation units **52** mediate the transport of downstream and upstream frames through those routing connections C1 to Cn-1.

Referring next to FIG. **28**, a specific communications system will now be described below, as an implementation of the above internetworking system **100** according to the present invention. This communications system **1***b* provides a heterogeneous network environment including two TCP/IP networks **81** and **82**, two Ethernet-based LANs **83** and **84**, and three OSI networks **85** to **87**. The first TCP/IP network **81** includes an NMS **10** and GNE **50-1** as its network nodes. The first OSI network **85** includes the GNE **50-1** and another GNE **50-2**, as well as two NEs **50***a* and **50***b*. The second TCP/IP network **82** includes the GNE **50-2** and two other GNEs **60** and **60***a*. The second OSI network **86** includes the GNE **60***a* and an NE **70***a*. The third OSI network **87** includes the GNE **60** and an NE **70**. The NMS **10**, GNE **50-1**, and NE **50***a* are interconnected by the Ethernet-based LAN **83**. The NE **50***a*, NE **50***b*, and GNE **50-2** are linked together. Also, the GNE **50-2** is linked with the GNEs **60***a* and **60** through the Ethernet-based LAN **84**. Further, the GNE **60***a* is linked with the NE **70***a*, and the GNE **60** is linked with the NE **70**. Transmission media used in this system include fiber optic cables.

In terms of the communication protocols, the system **1***b* is configured as follows. The NMS **10** employs a TCP/IP protocol stack, while the NEs **50***a*, **50***b*, **70***a*, and **70** have an OSI protocol stack. Further, the GNEs **50-1**, **50-2**, **60***a*, and **60** are armed with both TCP/IP and OSI protocol stacks.

The GNE **50-1** mediates the communication between the TCP/IP network **81** and OSI network **85** via the Ethernet-based LAN **83**. The GNE **50-2** mediates between the OSI network **85** and TCP/IP network **82**. The GNE **60***a* mediates between the TCP/IP network **82** and OSI network **86** via the Ethernet-based LAN **84**. Further, the GNE **60** mediates between the TCP/IP network **82** and OSI network **87** via the Ethernet-based LAN **84**.

The GNEs **50-1**, **50-2**, **60***a*, and **60**, and NEs **50***a*, **50***b*, **70***a*, and **70** have their own target identifiers (TIDs), allowing application entities to uniquely identify each of those network elements. More specifically, the GNE **50-1** has its unique TID "GNE#1." Likewise, the other GNEs **50-2**, **60***a*, and **60** have their own TIDs "GNE#2," "GNE#3," and "GNE#4," respectively. Further, the NEs **50***a*, **50***b*, **70***a*, and **70** have their own TIDs "NE#1," "NE#2," "NE#3," and "NE#4," respectively.

For illustrative purposes, it is assumed that the NMS **10** and GNE **50-1** have their respective IP addresses "IP001" and "IP010" in the domain of the TCP/IP network **81**. It is also assumed that the GNE **50-2**, GNE **60***a*, and GNE **60** have their respective IP addresses "IP020," "IP030," and "IP040" in the domain of the TCP/IP network **82**. With respect to the OSI network services, suppose that, within the OSI network **85**, the GNE **50-1**, **50-2**, NE **50***a*, **50***b* are identified by NSAP addresses "NSAP011," "NSAP012," "NSAP013," "NSAP014," respectively. It is also assumed that, within the OSI network **86**, the GNE **60***a*, NE **70***a* are referred to by their respective NSAP addresses "NSAP031" and "NSAP032." Within the OSI network **87**, the GNE **60** and NE **70** are given their NSAP addresses "NSAP041" and "NSAP042."

Consider here that, in the communications system **1***b*, the NMS **10** sends an ACT-USER command toward the NE **70** on the OSI network **87** to initiate its log-in session. In response to this command, the NE **70** returns a COMPLD message to the NMS **10** to indicate a response to the ACT-USER command. The following section will provide the details of this scenario.

FIG. **29** shows a situation where necessary TCP/IP connections and OSI associations have been established. More specifically, the following connections are available in the system **1***b*:

- TCP/IP connection C0 (first connection) between NMS **10** and GNE **50-1**
- OSI association A1 (routing connection) between GNE **50-1** and GNE **50-2**.
- TCP/IP connection C1 (routing connection) between GNE **50-2** and GNE **60**
- OSI association A2 (second connection) between GNE **60** and NE **70**

FIG. **29** also shows various frames flowing over the above connections. More specifically, "Frame A" denotes a downstream frame to be sent from the NMS **10** to the GNE **50-1**.

"Frame B" denotes a downstream frame to be sent from the GNE **50-1** to the GNE **50-2**. "Frame C" denotes a downstream frame to be sent from the GNE **50-2** to the GNE **60**. "Frame D" denotes a downstream frame to be sent from the GNE **60** to the NE **70**. "Frame E" denotes an upstream frame to be sent from the NE **70** to the GNE **60**. "Frame F" denotes an upstream frame to be sent from the GNE **60** to the GNE **50-2**. "Frame G" denotes an upstream frame to be sent from the GNE **50-2** to the GNE **50-1**. "Frame H" denotes an upstream frame to be sent from the GNE **50-1** to the NMS **10**. The detailed structures of those frames A to H will now be explained below, with reference to FIGS. **30**(A) to **33**(B),.

FIGS. **30**(A) and **30**(B) show the structures of frames A and B, respectively. Referring first to FIG. **30**(A), the frame A consists of a header field **701** and a TCP/IP data field **711**. The header field **701** carries a TCP/IP header containing an address "IP010." This address value indicates that the frame is destined for the GNE **50-1**. The TCP/IP data field **711** carries an ACT-USER command message addressed to the NE **70**. More specifically, the command line reads as follows:

ACT-USER:NE#4:ROOT:CTAG:ROOT;

Referring to FIG. **30**(B), the frame B consists of a header field **702** and an OSI data field **721**. The header field **702** carries an OSI header containing an address "NSAP012." This address value indicates that the frame is directed to the GNE **50-2**. The OSI data field **721** carries an ACT-USER command message addressed to the NE **70**, whose actual command line reads as follows:

ACT-USER:NE#4:ROOT:CTAG:ROOT;

FIGS. **31**(A) and **31**(B) show the structures of frames C and D, respectively. Referring first to FIG. **31**(A), the frame C consists of a header field **703** and a TCP/IP data field **731**. The header field **703** carries a TCP/IP header containing an address "IP040," which indicates that the frame is directed to the GNE **60**. The TCP/IP data field **731** carries an ACT-USER command message addressed to the NE **70**, whose actual command line reads as follows:

ACT-USER:NE#4:ROOT:CTAG:ROOT;

Referring to FIG. **31**(B), the frame D consists of a header field **704** and an OSI data field **741**. The header field **704** carries an OSI header containing an address "NSAP042," which indicates that the frame is directed the NE **70**. The OSI data field **741** carries an ACT-USER command message addressed to the NE **70**, whose actual command line reads as follows:

ACT-USER:NE#4:ROOT:CTAG:ROOT;.

FIGS. **32**(A) and **32**(B) show the structures of frames E and F, respectively. Referring first to FIG. **32**(A), the frame E consists of a header field **704***a* and an OSI data field **741***a*. The header field **704***a* carries an OSI header containing an address "NSAP041," which indicates that the frame is directed to the GNE **60**. The OSI data field **741***a* carries a C0MPLD response message addressed to the NMS **10**, whose actual command line reads as follows:

CTAG C0MPLD NE#4.

Referring to FIG. **32**(B), the frame F consists of a header field **703***a* and a TCP/IP data field **731***a*. The header field **703***a* carries a TCP/IP header containing an address "IP020," which indicates that the frame is directed to the GNE **50-2**. The TCP/IP data field **731***a* carries a C0MPLD response message addressed to the NMS **10**, whose actual command line reads as follows:

CTAG C0MPLD NE#4.

FIGS. **33**(A) and **33**(B) show the structures of frames G and H, respectively. Referring first to FIG. **33**(A), the frame G consists of a header field **702***a* and an OSI data field **721***a*. The header field **702***a* carries an OSI header containing an address NSAP011, which indicates that the frame is directed to the GNE **50-1**. The OSI data field **721***a* carries a C0MPLD response message addressed to the NMS **10**, whose actual command line reads as follows:

CTAG C0MPLD NE#4.

Referring to FIG. **33**(B), the frame H consists of a header field **701***a* and a TCP/IP data field **711***a*. The header field **701***a* carries a TCP/IP header containing an address "IP001," which indicates that the frame is directed to the NMS **10**. The TCP/IP data field **711***a* carries a C0MPLD response message addressed to the NMS **10**, whose actual command line reads as follows:

CTAG C0MPLD NE#4.

FIG. **34** shows a database T1 that the GNE **50-2** owns. This database T1 has two data fields to record IP addresses and TIDs. For instance, the first entry of the database T1 records a combination of IP address "IP030" and its corresponding TID "GNE#3."

Referring now to the flowcharts of FIGS. **35** to **38**, the following section will now describe how a command message is delivered from the NMS **10** to the NE **70**.

FIG. **35** is a flowchart which shows how the NMS **10** sends a frame A to the GNE **50-1**. In the following sequence, the step S71 is executed actually by the first connection setting unit **11** in the NMS **10**.

(S70) The NMS **10** obtains the IP address "IP010" of the GNE **50-1** by searching its local database, or by receiving information from a user.

(S71) With this IP address "IP010," the NMS **10** sets up a TCP/IP connection C0 to reach the GNE **50-1** according to the TCP/IP protocol.

(S72) The NMS **10** produces a frame A by inserting an ACT-USER command with a TID value "NE#4" into its TCP/IP data field **711**. The NMS **10** transmits this frame A to the GNE **50-1** through the established TCP/IP connection C0.

(S73) Upon receipt of the frame A, the GNE **50-1** parses the command line extracted from its TCP/IP data field **711**, according to the TCP/IP protocol specifications.

FIG. **36** is a flowchart which shows how a frame B is sent from the GNE **50-1** to the GNE **50-2**. In the following sequence, the step S84 (i.e., set-up of OSI association A1) is executed by the routing connection setting unit **51** in the GNE **50-1**.

(S80) The received command has a TID value "NE#4." Comparing this value with its own TID, the GNE **50-1** understands that the command is destined for some other network element. Now that the NSAP address corresponding to this TID is needed, the GNE **50-1** broadcasts a TARP resolve packet over the OSI network **85**, according to the OSI protocol specifications. As part of the OSI protocols, the TARP resolve packets are used to get the NSAP address associated with a specific TID.

(S81) Receiving the TARP resolve packet, the GNE **50-2** understands that the GNE **50-1** is seeking the NSAP address associated with NE#4.

(S82) The GNE **50-2** searches its local database T1, thus finding out that the target network element having the TID "NE#4" is located on a remote network that is reachable through the GNE **60**.

(S83) The GNE **50-2** sends back to the GNE **50-1** a pseudo TARP response packet containing the NSAP address "NSAP012" of the GNE **50-2** itself.

(S84) The GNE **50-1** receives the pseudo TARP response packet. With the NSAP address "NSAP012" obtained from this packet, the GNE **50-1** sets up an OSI association A1 reaching the GNE **50-2**, according to the OSI protocol.

(S85) The GNE **50-1** produces a frame B by inserting an ACT-USER command with a TID "NE#4" into its OSI data field **721**. It then transmits this frame B to the GNE **50-2** through the pre-established OSI association A1.

(S86) Upon receipt of the frame B, the GNE **50-2** parses the command line extracted from its OSI data field **721**, according to the OSI protocol specifications.

FIG. **37** is a flowchart which shows how a frame C is sent from the GNE **50-2** to the GNE **60**. In the following sequence, the step S91 (i.e., set-up of TCP/IP association C1) is executed by the routing connection setting unit **51** in the GNE **50-2**.

(S90) The received command has a TID value "NE#4." Comparing this value with its own TID, the GNE **50-2** understands that the command is destined for some other network element. The GNE **50-2** collects an IP address "IP040" from the GNE **60**.

(S91) According to the TCP/IP protocols, the GNE **50-2** sets up a TCP/IP connection C1 reaching the GNE **60**.

(S92) The GNE **50-2** produces a frame C by inserting an ACT-USER command with a TID "NE#4" into its TCP/IP data field **731**. It then transmits this frame C to the GNE **60** through the established TCP/IP connection C1.

(S93) Upon receipt of the frame C, the GNE **60** extracts a command from the TCP/IP data field **731** and parses it according to the TCP/IP protocol specifications.

FIG. **38** is a flowchart which shows how a frame D is sent from the GNE **60** to the NE **70**. In the following sequence, the step S103 (i.e., set-up of OSI association A2) is executed actually by the second connection setting unit **51** in the GNE **60**.

(S100) The received command has a TID value "NE#4." Comparing this value with its own TID, the GNE **60** understands that the command is destined for some other network element. Seeking the NSAP address associated with this TID, the GNE **60** broadcasts a TARP resolve packet over the OSI network **87**, in accordance with the OSI protocol specifications.

(S101) Receiving the TARP resolve packet, the NE **70** understands that the GNE **60** is seeking the NSAP address associated with NE#4.

(S102) The NE **70** sends back to the GNE **60** a TARP response packet containing the NSAP address "NSAP042" of the NE **70** itself.

(S103) With the obtained NSAP address "NSAP042," the GNE **60** sets up an OSI association A2 reaching the NE **70**, according to the OSI protocols.

(S104) The GNE **60** produces a frame D by inserting an ACT-USER command with the TID "NE#4" into its OSI data field **741**. It then transmits this frame D to the NE **70** through the established OSI association A2.

(S105) Upon receipt of the frame D, the NE **70** parses the command line extracted from its OSI data field **741**, according to the OSI protocol specifications. Recognizing it as an ACT-USER command, the NE **70** initiates a log-in session.

When the log-in session is finished, the NE **70** returns a response message to notify the NMS **10** of the completion. More specifically, the NE **70** produces a frame E containing a response message and passes it to the GNE **60**. The GNE **60** then creates and sends a frame F to the GNE **50-2**, which subsequently causes the GNE **50-2** to assemble and send a frame G to the GNE **50-1**. Finally, the GNE **50-1** produces and sends a frame H to the NMS **10**. In this way, the response message is reloaded into different frames by a plurality of GNEs, while being relayed over the pre-established TCP/IP connections and OSI associations.

The next section will present another version of the communications system **1***b*. Recall that the above-described system **1***b* established the following four connections to relay the frames:

TCP/IP connection C0 between NMS **10** and GNE **50-1**,

OSI association A1 between GNE **50-1** and GNE **50-2**,

TCP/IP connection C1 between GNE **50-2** and GNE **60**, and

OSI association A2 between GNE **60** and NE **70**.

In contrast to this, the modified communication system **1***c* establishes only two connections to do the same. They are:

TCP/IP connection C0 between NMS **10** and GNE **50-1**, and

Direct connection between GNE **50-1** and NE **70**.

FIG. **39** shows a situation where the above-noted TCP/IP connection and OSI association have been established in the modified communications system **1***c*. Here, the system **1***c* has set up a TCP/IP connection C0 between the NMS **10** and GNE **50-1** and an OSI association between the GNE **50-1** and NE **70**.

FIG. **29** also shows various frames flowing over the above connections. More specifically, "Frame A" denotes a downstream frame to be sent from the NMS **10** to the GNE **50-1**. "Frame I" denotes a downstream frame to be sent from the GNE **50-1** or GNE **60** toward the NE **70**. "Frame J" denotes a downstream frame to be sent from the GNE **50-2** to the GNE **60**. "Frame K" denotes an upstream frame to be sent from the NE **70** to the GNE **50-1**. "Frame H" denotes an upstream frame to be sent from the GNE **50-1** to the NMS **10**.

Referring next to FIGS. **40**(A), **40**(B), and **41**, the structures of frames I, J, and K will be explained in detail below. (See earlier part of the specification for details of other frames A and H)

FIGS. **40**(A) and **40**(B) show the structures of frames I and **J**, respectively. Referring first to FIG. **40**(A), the frame I has a header field **705** and an OSI data field **751**. The header field **705** carries an OSI header containing an address "NSAP042." This address value indicates that the frame I is directed the NE **70**. The OSI data field **751** carries an ACT-USER command addressed to the NE **70**. More specifically, the command line reads as follows:

```
ACT-USER:NE#4:ROOT:CTAG:ROOT;
```

Referring to **40**(B), the frame J has a header field **706** and a TCP/IP data field **761**. The header field **706** carries a TCP/IP header containing an address IP address "IP040," which indicates that the frame is destined for the GNE **60**. The TCP/IP data field **761** is loaded with the frame I as a whole.

FIG. **41** shows the structure of frame K. The frame K consists of a header field **706***a* and an OSI data field **761***a*. The header field **706***a* carries an OSI header containing an address "NSAP011," which indicates that the frame is

directed to the GNE **50-1**. The OSI data field **761***a* carries a C0MPLD response message addressed to the GNE **50-1**, which reads as follows:

CTAG C0MPLD NE#4.

FIG. **42** shows databases T2 and T3 being employed in the GNE **50-2** to store the configuration data of the communications system **1***c*. The database T2 has a data field entitled "Neighbor's NSAP Address." In the present context, this field stores the NSAP addresses of the GNEs **60***a* and **60** which are adjacent to the GNE **50-2**. The database T3, on the other hand, has the following data fields: "NSAP Address Prefix" and "IP Address." The first entry, for example, shows a combination of NSAP address prefix "NSAP03" and IP address "IP030," which are parameters of the GNE **60***a*. The next entry indicates another combination of NSAP address prefix "NSAP04" and IP address "IP040," which are parameters of the GNE **60**.

FIGS. **43** and **44** show a flowchart describing how the GNE **50-1** delivers a specific frame to the NE **70**. It is assumed here that the NMS **10** has transmitted a frame A to the GNE **50-1**. This process, however, will not be explained here, because it is similar to what has been described earlier in FIG. **35**.

(S110) The GNE **50-1** receives the frame A with a TID value "NE#4." Comparing this value with its own TID, the GNE **50-1** understands that the command is destined for some other network element. Seeking the NSAP address associated with this TID, the GNE **50-1** broadcasts a TARP resolve packet over the OSI network **85**, in accordance with the OSI protocol specifications.

(S111) The GNE **50-2** receives the TARP resolve command packet. It then searches its local database T2 to obtain the NSAP address "NSAP041" of the GNE **60**.

(S112) The GNE **50-2** searches another local database T3 by using "NSAP041" as the keyword. This search yields the IP address "IP040" assigned to the GNE **60**.

(S113) The GNE **50-2** redirects the TARP resolve packet to the obtained IP address "IP040," i.e., to the GNE **60**.

(S114) Receiving the TARP resolve packet from the GNE **50-2**, the GNE **60** broadcasts it over the OSI network **87**.

(S115) Receiving the TARP resolve packet, the NE **70** understands that the GNE **50-1** is seeking the NSAP address of the NE **70** itself.

(S116) The NE **70** transmits to the GNE **50-1** a TARP response packet containing its own NSAP address "NSAP042."

(S117) With obtained NSAP address "NSAP042," the GNE **50-1** sets up an OSI association A3 reaching the NE **70**, according to the OSI protocol.

(S118) The GNE **50-1** produces a frame I by inserting an ACT-USER command with a TID "NE#4" into its OSI data field **751**. The GNE **50-1** then sends it out through the OSI association A3.

(Sll9) Upon receipt of the frame I, the GNE **50-2** produces a frame J by inserting the received frame I into the TCP/IP data field **761**. The GNE **20** then sends out this frame J to the GNE **60**.

(S120) When the frame J arrives, the GNE **60** extracts the frame I from the received frame J and sends it to the NE **70**.

(S121) Upon receipt of the frame I, the NE **70** extracts and parses its command line according to the OSI protocol specifications. Recognizing it as an ACT-USER command, the NE **70** initiates a log-in session.

When the log-in session is finished, the NE **70** returns a response message to notify the NMS **10** of the command completion. More specifically, the NE **70** produces a frame K containing a response message and sends it to the GNE **50-1** through the OSI association A3. The GNE **50-1** then produces a frame H and sends it to the NMS **10**.

The next section will now describe how the GNEs update their databases. FIG. **45** shows a situation where one NE **71** has been newly added to the above-described communication system **1***b*. More specifically, this new NE **71** is assigned a TID "NE#5" and NSAP address "NSAP043" and connected to the GNE **60** as a node on the OSI network **87**. The other elements of the system are the same as those shown in FIG. **28**.

FIG. **46** shows a situation where two TCP/IP connections have been established in the system of FIG. **45**. Those TCP/IP connections are intended for the use in a process of updating the databases so as to cover the newly added NE **71**. The established connections include: a TCP/IP connection Cb between the GNE **60** and GNE **50-2**, and a TCP/IP connection Cc between the GNE **60** and GNE **60***a*. In FIG. **46**, "Frame L" denotes a frame to be sent from the GNE **60** to the GNE **50-2**, while "Frame M" denotes a frame to be sent from the GNE **60** to the GNE **60***a*.

Referring now to FIGS. **47**(A) and **47**(B), the detailed structures of frames L and M will be described below. FIGS. **47**(A) and **47**(B) show the structures of frames L and M, respectively. Referring first to FIG. **47**(A), the frame L consists of a header field **801** and a TCP/IP data field **811**. The header field **801** carries a TCP/IP header containing an address IP address "IP020," which indicates that the frame is directed to the GNE **50-2**. The TCP/IP data field **811***a* conveys an UPDATE-DB command which requests the recipient (i.e., GNE **50-2**) to update its database. More specifically, this command line reads as follows:

UPDATE-DB:GNE#2:CTAG:IP040.NSAP043;

Referring to FIG. **47**(B), the frame M consists of a header field **802** and a TCP/IP data field **821**. The header field **802** carries a TCP/IP header containing an IP address "IP030," indicating that the frame is addressed to the GNE **60***a*. The TCP/IP data field **821** conveys an UPDATE-DB command which requests the recipient (i.e., GNE **60***a*) to update its database. More specifically, this command line reads as follows:

UPDATE-DB:GNE#3:CTAG:IP040.NSAP043;

FIG. **48** is a flowchart describing how the recipients of an UPDATE-DB command update their databases. The following explanation assumes that a new NE **71** is added to the OSI network **87** (physically, connected to the GNE **60**) as previously noted.

(S130) According to the OSI protocols, the NE **71** sends a routing packet which indicates that it has become a new member of the OSI network **87**.

(S131) The GNE **60** receives the routing packet. Comparing the contents of the packet with the records in its local database, the GNE **60** understands that some change has occurred in the network configuration.

(S132) The GNE **60** then obtains the GNE **50-2**'s IP address "IP020" and the GNE **60***a*'s IP address "IP030," consulting its local database.

(S133) Using the obtained IP addresses (IP020 and IP030), the GNE **60** sets up two TCP/IP connections reaching the GNEs **50-2** and **60***a*.

(S134) The GNE **60** produces frames L and M containing a database update command in their TCP/IP data field. The database update command in the frame L has a TID

"GNE#2," while that in the frame M has a TID "GNE#3." The GNE **60** transmits those frames L and M to the GNE **50-2** and **60***a*, respectively, through the TCP/IP connections.

(S135) The GNE **50-2** receives the frame L, and extracts the database update command from its TCP/IP data field according to the TCP/IP protocol specifications.

(S136) The GNE **50-2** extracts the TID "GNE#2" from the received database update command. Recognizing that the command is directed to itself, the GNE **50-2** updates its local databases, parsing the command line. (S137) The GNE **60***a* receives the frame M, and extracts the database update command from its TCP/IP data field according to the TCP/IP protocol specifications.

(S138) The GNE **60***a* extracts the TID "GNE#3" from the received database update command. Recognizing that the command is directed to itself, the GNE **60***a* updates its local databases, parsing the command line.

The above section has discussed the internetworking system using routing connections. The following section will now present an internetworking method according to the present invention, with reference to the flowchart of FIG. **49**. The explanation assumes the communications system **1***b* described earlier in FIG. **29**.

(S140) The NMS **10** sets up a first connection (TCP/IP connection C**0**) reaching the GNE **50-1**.

(S141) The NMS **10** produces a downstream frame containing the identifier of the NE **70** of interest.

(S142) The NMS **10** sends out the downstream frame through the connection C**0**. The NMS **10** also handles upstream frames received through the connection C**0**, if any.

(S143) With its routing control functions, the GNE **50-1** sets up a routing connection (OSI association A**1**) reaching the GNE **50-2**.

(S144) The GNE **50-1** mediates the transport of downstream and upstream frames through the routing connection.

(S145) The GNE **60** sets up a second connection (OSI association A**2**) reaching the NE **70**.

(S146) The GNE **60** mediates the transport of downstream and upstream frames through the second connection.

The above-described invention provides an internetworking system **100** and internetworking method which use GNEs deployed on the network to render mediation services. Each GNE employs its local databases for storing records about neighboring nodes, which allows the GNE itself to provide routing services (selection of routing paths) according to a given destination address. This feature enables more efficient internetworking in multiprotocol environments. Further, the databases are automatically updated when any changes occur in the network configuration, which improves the system's flexibility and simplifies the user tasks of network monitoring and maintenance.

All the above discussion will now be summarized below. According to the present invention, the internetworking system comprises a network management station and a mediation device. For transport of frames, they establish a first connection between them in a point-to-point fashion, as well as a second connection between the mediation device and the intended network elements in a point-to-multipoint fashion. This feature of the invention enables heterogeneous networks to efficiently communicate with each other, mediating between different protocols.

Also, the proposed internetworking method establishes a first connection in a point-to-point fashion and a second connection in a point-to-multipoint fashion to transport frames. This enables heterogeneous networks to efficiently communicate with each other, mediating between different protocols.

Further, the present invention proposes another internetworking system. This system establishes a first connection between a network management station and a second mediation device in a point-to-point fashion, and then a routing connection from the second mediation device to a first mediation device. It further establishes a second connection from the first mediation device to an intended network element(s) in a point-to-multipoint or point-to-multipoint fashion. Frames are transported over those connections. This enables heterogeneous networks to efficiently communicate with each other, mediating between different protocols.

Further, according to another proposed internetworking method, a first connection (point-to-point), a routing connection, and a second connection (point-to-point or point-to-multipoint) are established to transport frames. This enables heterogeneous networks to efficiently communicate with each other, mediating between different protocols.

The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.

What is claimed is:

**1**. An internetworking system for interconnecting first and second networks that use different protocols, comprising:

(a) a network management station on the first network, comprising:

first connection setting means for establishing a point-to-point connection over the first network,

downstream frame producing means for producing a downstream frame containing identifiers of a plurality of network elements on the second network that said network management station intends to interact with, and

frame communication means for sending out the downstream frame through the point-to-point connection; and

(b) a mediation device disposed between the first and second networks, comprising:

second connection setting means for establishing a point-to-multipoint connection over the second network to reach the plurality of network elements, in association with the point-to-point connection over the first network, and

frame mediation means for receiving the downstream frame through the point-to-point connection and forwarding the received downstream frame to the plurality of network elements through the point-to-multipoint connection.

**2**. The internetworking system according to claim **1**, wherein said mediation device further comprises a connection database that records the identifiers of the plurality of network elements and associated point-to-point and point-to-multipoint connections.

**3**. The internetworking system according to claim **2**, wherein said frame mediation means converts between different protocols used in the first and second networks, based on said connection database, thereby mediating between the first and second networks.

**4**. A network management station disposed on a first network to manage a plurality of network elements on a

second network whose protocol is different from the first network's protocol, the first and second network being interconnected by a mediation device, the network management station comprising:

connection setting means for establishing a point-to-point connection to the mediation device over the first network, as well as causing the mediation device to establish a point-to-multipoint connection reaching the plurality of network elements in association with the point-to-point connection;

downstream frame producing means for producing a downstream frame containing identifiers of the plurality of network elements that the network management station intends to interact with; and

frame communication means for sending out the downstream frame through the point-to-point connection, thereby causing the mediation device to relay the downstream frame to the plurality of network elements through the point-to-multipoint connection.

5. A mediation device which mediates between first and second networks that use different protocols, the mediation device comprising:

connection setting means for establishing a point-to-multipoint connection to reach a plurality of network elements on the second network, in association with a point-to-point connection that a network management station on the first network establishes to reach the mediation device; and

frame mediation means for relaying a downstream frame from the network management station on the first network to the plurality of network elements on the second network through the point-to-multipoint connections, the downstream frame containing identifiers of the plurality of network elements on the second network.

6. An internetworking method for interconnecting first and second networks that use different protocols, comprising the steps of:

(a) at a network management station on the first network, establishing a point-to-point connection to a mediation device disposed between the first and second networks;

(b) at the network management station, producing a downstream frame containing identifiers of a plurality of network elements on the second network whose communication protocol is different from that of the first network;

(c) sending out the downstream frame from the network management station through the point-to-point connection;

(d) at the mediation device, establishing a point-to-multipoint connection over the second network to reach the plurality of network element in association with the point-to-point connection; and

(e) at the mediation device, receiving the downstream frame through the point-to-point connection over the first network and forwarding the received downstream frame to the network elements on the second network through the point-to-multipoint connection.

7. The internetworking method according to claim 6, further comprising the step of providing a connection database in the mediation device that records the identifiers of the plurality of network elements and associated point-to-point and point-to-multipoint connections,

wherein said receiving and forwarding step (e) converts between different protocols used in the first and second networks, based on said connection database, thereby mediating between the first and second networks.

8. An internetworking system for interconnecting first and second networks that use different protocols, the first and second networks being separated by at least one intermediate network, comprising:

(a) a network management station on the first network, comprising:

first connection setting means for establishing a point-to-point connection over the first network,

downstream frame producing means for producing a downstream frame containing identifiers of a plurality of network elements on the second network that said network management station intends to interact with, and

frame communication means for sending out the downstream frame through the point-to-point connection,

(b) a first mediation device disposed between the second network and the intermediate network, comprising:

second connection setting means for establishing a point-to-multipoint connection over the second network to reach the plurality of network elements, in association with the point-to-point connection over the first network, and

first frame mediation means for relaying the downstream frame to the plurality of network elements through the point-to-multipoint connection; and

(c) a second mediation device disposed between the first network and intermediate network, comprising:

routing connection setting means for establishing a routing connection over the intermediate network to reach the first mediation device, by performing routing control, thereby substantially extending the point-to-point connection up to the first mediation device, and

second frame mediation means for relaying the downstream frame from the network management station to the first mediation device through the routing connection.

9. The internetworking system according to claim 8, wherein first and second mediation devices further comprise a database storing neighborhood records about neighboring network elements.

10. The internetworking system according to claim 9, wherein said database is automatically updated with a new neighborhood record, according to a change in the neighboring network elements.

11. A mediation device for use in an internetworking system having first and second networks separated by an intermediate network, the mediation device being disposed between the first network and intermediate network, a point-to-point connection being established over the first network, a point-to-multipoint connection established over the second network, the mediation device comprising:

routing connection setting means for establishing a routing connection over the intermediate network in association with the point-to-point connection by performing routing control, thereby substantially extending the point-to-point connection up to another mediation device that is disposed between the intermediate network and second network; and

frame mediation means for relaying a downstream frame from a network management station on the first network to said another mediation device through the established routing connection, the downstream frame containing identifiers of a plurality of network elements

on the second network that the network management station intends to interact with;

whereby the downstream frame from the network management station on the first network is delivered to the plurality of network elements on the second network through the point-to-point connection, routing connection, and point-to-multipoint connection.

**12**. A mediation device for use in an internetworking system having first and second networks separated by an intermediate network, the mediation device being disposed between the intermediate network and second network, a point-to-point connection being established over the first network, a routing connection being established over the intermediate network, the mediation device comprising:

connection setting means for establishing a point-to-multipoint connection over the second network in association with the routing connection over the intermediate network, to reach a plurality of network elements on the second network; and

frame mediation means for relaying a downstream frame from a network management station on the first network to the plurality of network elements through the established the point-to-multipoint connection, the downstream frame containing identifiers of the plurality of network elements on the second network that the network management station intends to interact with;

whereby the downstream frame from the network management station on the first network management station on the first network is delivered to the plurality of network elements on the second network through the point-to-point connection, routing connection, and point-to-multipoint connection.

**13**. An internetworking method for interconnecting first and second networks that use different protocols, the first and second network being separated by at least one intermediate network, the method comprising the steps of:

(a) at a network management station on the first network, establishing a point-to-point connection to a second mediation device disposed between the first network and intermediate network;

(b) at the network management station, producing a downstream frame containing identifiers of a plurality of network elements on the second network;

(c) sending out the downstream frame from the network management station through the point-to-point connection;

(d) at the second mediation device, establishing a routing connection over the intermediate network by performing routing control, thereby extending the point-to-point connection up to a first mediation device that is disposed between the intermediate network and second network;

(e) at the second mediation device, relaying the downstream frame from the network management station to the first mediation device through the routing connection;

(f) at the first mediation device, establishing point-to-multipoint connection to reach the network elements; and

(g) at the first mediation device, relaying the downstream frame from the second mediation device to the plurality of network elements through the point-to-multipoint connection.

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